A POPULAR GUIDE
to MINERALS

With chapters on the Bement Collection of Minerals in the American
Museum of Natural History, and The Development of Miner-
alogy; for use of visitors to public cabinets of minerals
and for elementary teaching in mineralogy.

BY

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American Museum Natural History

*WITH 400 TEXT ILLUSTRATIONS
AND 74 PHOTOGRAPHIC PLATES*

CONTAINING A MAP OF THE
DISTRIBUTION OF MINERALS IN
THE UNITED STATES

PREFACE

This guide is intended for use by visitors to collections of minerals. While the arrangement may not be always the same in all collections, there can be but slight deviation from the commonly accepted succession given in Dana's "System of Mineralogy" (5th and 6th editions).

Specimens of the various representative species of minerals will also be found to resemble each other, and illustrations and comments drawn from one highly developed collection will be found usually applicable to all others.

The following pages may be found useful by almost all visitors to mineral collections, and in itself is a convenient reference.

The order observed in this Guide is that of the fifth edition of Dana, but this in no way interferes with the use of the Guide when the collection inspected is arranged by that of the sixth, or in any other way, as long as the broader divisions retain their usual succession, as Elements, Sulphides, etc., Oxides, and Oxygen Salts, including Silicates. The position of the carbonates before or after the silicates, or the deviation from the plan of the Guide in the position of some mineral species, cannot diminish its usefulness, as of course in all collections, minerals of the same species or name are brought together.

An alphabetically arranged Index assists the visitors to collections, public or private, to find at once any mineral he may be examining.

Some of the figures of crystals in the following pages were kindly loaned by John Wiley & Sons, New York, the publishers of Dana's "System of Mineralogy"; the figures of specimens of the Bement Collection in the American Museum of Natural History, were used through the kind permission of its director, and the Chapter on the History of Mineralogy, by permission of the publishers of the *Scientific American.*

This Guide is applicable also to collections in which the species are grouped around a predominant base, by the use of the Index. It contains a reference to the famous Bement Collection, and plates illustrative of specimens to be seen in that cabinet. It has been greatly augmented in text and illustrations over the first edition, and the author has ventured, in its introductory portion, to suggest teaching lessons to teachers.

PREFACE

In a very slight way the first portions of the Guide review some of the scientific aspects of Mineralogy in relation to crystallography, optics, chemistry, geology, etc., and have been introduced, and are only meant to serve the purpose of a popular or elementary elucidation for those, whose interest or curiosity may be so far stimulated by their inspection of large public collections of minerals, as to wish to learn more about the principles which to-day, in their harmonious conjunction, form the Science of Mineralogy. They may also serve the useful purpose of directing their readers' attention to larger and more copious works of reference.

L. P. G.

New York,
April 15, 1912.

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INTRODUCTION

MINERALOGY as a science treats of the elements and of all the combinations of the elements which are found upon the earth in a state of nature, and may incidentally refer to those combinations of the elements which have, as in meteorites, entered our atmosphere from space, or those industrially produced salts and compounds which have been artificially made. All such combinations in a comprehensive sense are *salts* or *chemical compounds,* those terms meaning a definite and invariable, or almost invariable, union of elements into a chemical whole or unit; so that Mineralogy is the Science of the Elements and their Salts and Compounds, as found in and upon the earth, and these natural groupings of the elements are called **Minerals.**

Such groupings of the elements may form the *inorganic* compounds, viz, those compounds which have no reference to and are not included in animal or vegetable organisms, as quartz, mica, feldspar, the ores, alkaline salts, and gems; and the *organic* compounds, viz, those compounds originating in animal or vegetable organisms, and generally, so far as treated in this science, resulting from their change by decomposition or distillation, as the mineral oils, coal, asphalts, fossil resins, and gases.

Mineralogy discusses minerals from three points of view: first, their form, which has produced the science of **Crystallography;** second, their composition and qualities, which has produced the science of **Determinative Mineralogy;** and third, their occurrence and appearance, which has produced the science of **Descriptive Mineralogy.**

CRYSTALLOGRAPHY is the study of crystals. The greater number of minerals in their molecular constitution are controlled by certain geometrical tendencies which bring them into a certain and limited number of forms, forms bounded by planes and limited by edges, which forms preserve for each mineral an identity of character, and which forms are known as crystals. With these crystalline forms are associated certain optical qualities, as double refraction, dichroism, asterism, etc., which more properly are embraced under **Determinative Mineralogy.**

DETERMINATIVE MINERALOGY tells us what minerals are composed of, supplies us with chemical formulæ which express in symbols this composition, acquaints us with methods for finding out their constituents, gives us a convenient list of reactions, or their behavior when exposed to high heats and treated with chemical reagents, describes their peculiar optical properties and records their hardness, luster, specific gravity, cleavage or *breakage,* and texture.

DESCRIPTIVE MINERALOGY gives the names and describes the occurrence of minerals, how and where they are found, their association one with another, their colors, frequency and varieties, it points out local peculiarities in minerals, and dwells especially upon the distribution of minerals, suggests their history and traces or describes their changes. The body of this Guide belongs to this section.

These three departments of mineralogy form a complete index to the attributes of minerals, and when taken in connection with each other, compose a guide by which minerals are scientifically named and understood. A few pages only can be devoted to the elucidation of the former two in this Guide, but some understanding of their value and contents is especially essential for an intelligent appreciation of any classified collection of minerals, and for any scientific recognition of the nature and economy of minerals themselves, as individuals, as species and as groups.

CRYSTALLOGRAPHY

Substances either elements or compounds of the elements take on a *crystalline* condition when they become solid from a state of vapor, or from solution or from fusion. An example of the first is where iodine, arsenic, camphor, pass from a vaporous or gaseous state into a solid form upon cooling; an example of the second is the familiar formation of salt crystals from an evaporating solution which, as it becomes concentrated, liberates the *chloride of sodium* from its dissolved state, and the solid molecules of salt cohere together in cubical crystals; an example of the third is readily seen in freezing water forming the crystalline mass *ice,* though here the individual crystals are so compacted as to form a surface, and similarly, sulphur, solidifying from fusion, *crystallizes.*

More remarkable than these instances of crystallization, from liquid and vaporous conditions is the assumption of crystallographic forms by solids. Thus the red iodide of mercury, having one crystalline form, will change to the yellow iodide of ·mercury of a

different crystalline form upon a change of heat, and an *uncrystal-lized* oxide of arsenic (*arsenious anhydride*) develops after a time *octahedral* crystals. These peculiar changes have been observed in natural minerals.

But while unusual phenomena of this kind arrests attention, and we have many dimorphous and even polymorphous salts, there is a wonderful fixity in the crystallization of those natural salts or compounds we call minerals. Topaz, beryl, quartz, calcite, pyrite, corundum, crystallize in certain ways, exhibiting, under a general law of uniformity, a wide diversity of forms, and, wherever found, at whatever age of the earth's history formed, however much contrasted in color or appearance evince the control of an inflexible crystallographic law. This is a principle of precision which enables the Mineralogist to determine minerals, while most obviously it gives to minerals an almost unapproachable interest and distinction among the objects of nature.

All crystals as bounded by planes make symmetrical solids, which can be separated into six classes or kinds of forms, and these classes rest upon two fundamental assumptions; first, that each crystal contains three or more *axial* directions, and second, that these *axial directions* in each class retain to each other an *invariable relation,* and these *directions* further are demonstrably related to the *physical* properties of the crystals, as *hardness, cleavage, elasticity,* their *optical* and *electrical* properties.

To take a particular instance of a crystal and by way of illustration, a cube is a solid or crystal bounded by six surfaces, and the relation of width, depth and height of these surfaces is unity, or all the same. We can imagine that three axes at right angles to each other and intersecting at the exact center of the cube are imbedded in the cube, and that each passes to the exact center of the two opposite faces or planes which cut off the two ends of

Fig. 1

each axis (Fig. 1). These three axes, *a, b, c,* would be the imaginary lines, parallel to which the bounding planes of the cube would pass, cutting them all at equal distances from the solid center of the cube. In other words, the idea of the cube, as a form, could be expressed by saying that it held three equal axes at right angles to each other, limited by six planes at right angles to each other also. And such an expression forms the *norm* or
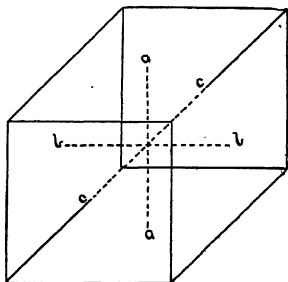
rule of axial relations for one of these six classes, to which all crystals are referred. This first class is called in crystallography the **Isometric System**. It possesses in all its forms three imaginary axes (axial directions), which are at right angles to each other and of equal length. From a simple primary form, as the cube in this system, there is developed a variety of other forms by replacing the edges or angles of the cube by truncating planes, whose intersections, when produced, form the edges of new crystalline shapes, in all of which, however, the three axes which may be drawn or imagined (axial directions) within each crystal, remain equal and at right angles. Thus in Fig. 34 we have the cube, in Fig. 39 we see its solid angles replaced by planes which, when produced, intersect and form an octahedron (Fig. 35) in which the three axes are still maintained equal and at right angles to each other. An inspection of this plate will similarly show the development of a number of derivative forms created by thus replacing the edges and angles of the cube by equally inclined planes.

In crystallography all of these forms are given distinctive names, and they are furthermore exemplified and expressed in formulæ which are in all cases symbols which indicate the geometrical relations of the bounding planes of the crystals to the axes. For instance, choosing amongst a number of varying styles, the symbolism of Naumann, the cube or hexahedron of the Isometric System would be expressed by the symbols ∞ o ∞ (infinity, zero, infinity), which as applied to any one and all planes of this crystal, tell us that they touch one axis or are at *no* distance from it, viz, zero, o, and that they can never touch or intersect the other two, or are parallel to them, and therefore remain practically *infinitely* removed from them, viz, infinity, ∞. In other words, crystallographic symbols are composed of *three* signs (in the case of the Hexagonal System of four) which have reference to the geometrical relation of a crystalline plane to the *three* axes of the crystal. Such crystalline forms as contain the entire complement of faces possible to one crystal are called *holohedral* as distinguished from forms which result from a symmetrical development of one half the faces. Thus in Fig. 66 is a *hemihedral* phase of an octahedron, or, it results from the symmetrical development of the alternate faces of Fig. 35, and its relation to the cube or hexahedron is seen in the alternate truncating planes of the cube in Fig. 64. But the possibility of hemihedrism is obviously limited by the possibility of selecting and producing alternate faces so as to enclose a solid. There can be no hemihedral form

to a cube. Still hemihedral faces, as half domes, half pyramids, half prisms, appear on crystals in combination with other faces making *closed* forms. These half domes, pyramids, and prisms, would not have enclosed in a solid, but appear as faces upon crystals which are completed by other faces. Still a cube *form* may be considered hemihedral, when it is the *limit* form of a *hemihedral* crystal, as of the diploid, in pyrite.

Let us consider an *octahedron* in the Isometric system. It is an eight-sided crystal. It therefore contains two more faces than a cube. It is, or can be, built up on three axes as right angles to each other, and each axis is *intercepted* at an equal distance from the *origin* X (Fig. 2) by the octahedron's faces. Its faces are
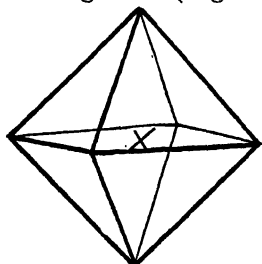
Fig. 2

triangles, and in contrast with the cube, each of these equilateral triangular faces touches or cuts all of the three axes, and is parallel to none. In the cube o was used in the formula, expressing the relations of its faces to the structural axes, as pertaining to that face which touched or intercepted an axis, and ∞ or infinity as expressing its parallelism to the other axes. The eight faces of the octahedron are symmetrically disposed with regard to the three axes, (except as they lie in different octants) and, as they touch or cut the three axes at equal distances from the origin, the formula for the octahedral form becomes o o o or simply o. Had these faces cut two of the axes at equal distances, but the third at a different (greater or less) distance from the origin the formula might become *m* o o as in the trigonal trisoctahedron (See Fig. 3) or *m* o *m* as in the tetragonal trisoctahedron (Fig. 4) or if they had cut all axes unequally *m* o *n* as in the hexoctahedron (Fig. 5). The Octahedron is made the primary form of the system to which it is
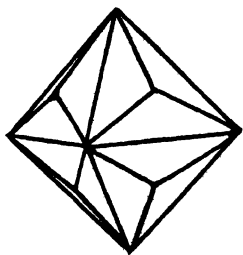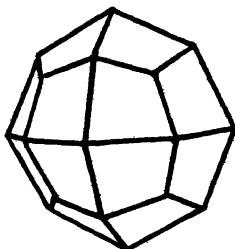

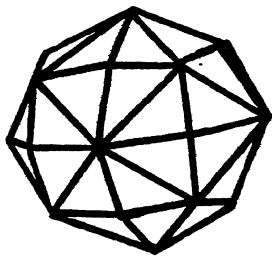
Fig. 3   Fig. 4   Fig. 5

referred; viz, the Isometric, though the various forms of this system could be derived also from the cube by replacement of its edges or by truncation of its angles, as can, in a measure, be seen in the figures on Plate I.

The axes, assumed as lines of construction, and with reference to which the formulæ of the faces of a crystal, express the relation of those faces to these assumed axes—these axes are, at least, demonstrably, *directions* of force and accretion, in other words, there is *polarity* in the development of crystals. This is shown in skeleton forms of crystals, where elemental units, in the shape of minute or small crystals, have united along lines at right angles to
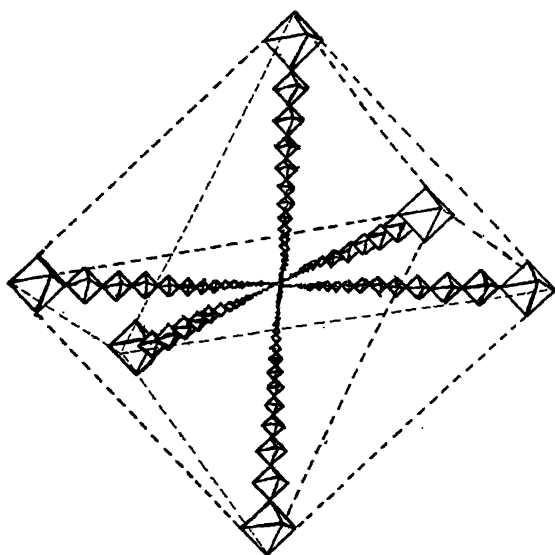

Fig. 6

each other, as in the silver of Alva, Scotland, (Fig. 6), forming a skeletal frame or scaffolding for an octahedron, to be filled out; while on each line a progressive enlargement is noticed, the terminal crystal forming the solid angle of the contemplated octahedron. Similarly, hollow cubes of *salt* or hollow octahedrons of *cuprite* evince a predominant segregation along edges which are parallel
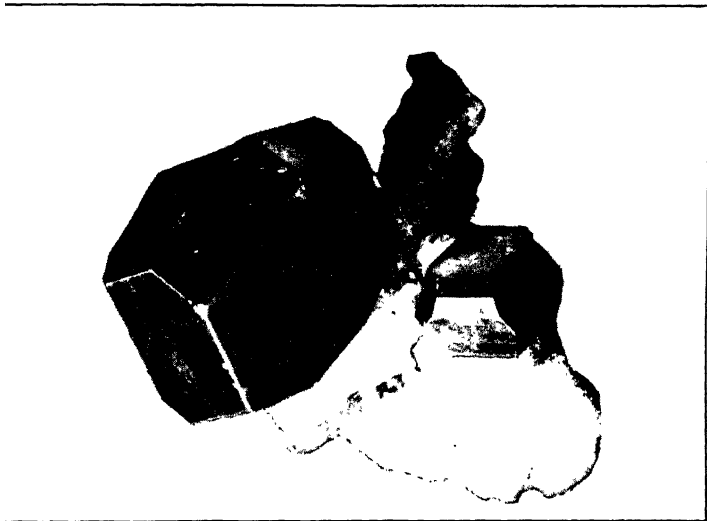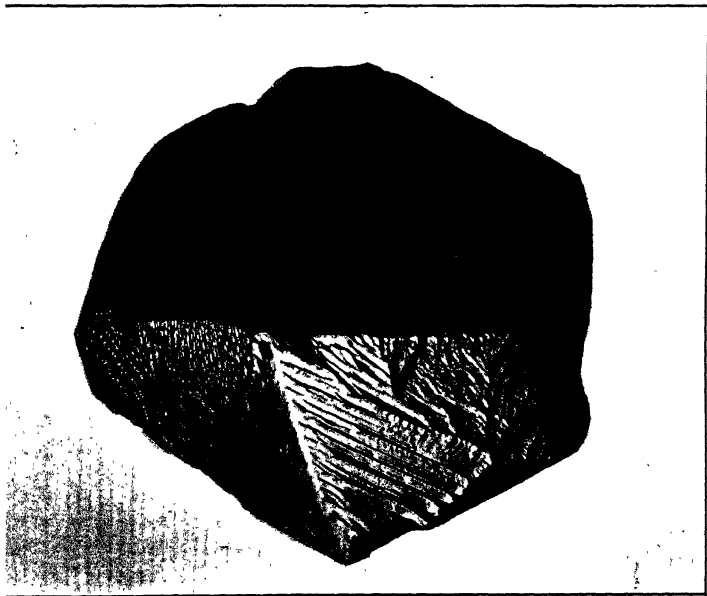
SULPHUR
Cianciana, Sicily, Italy
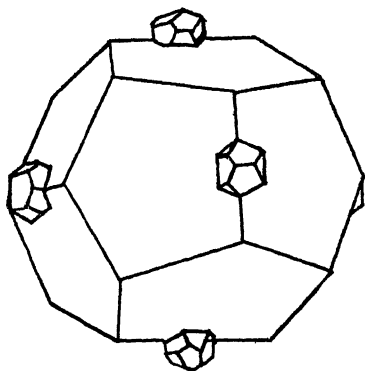Bement Collection, American Museum of Natural History

Fig. 7

to the assumed axes. Prof. Heddle furnishes a striking illustration of polar tendencies (Fig 7), in a crystal of pyrite (pentagonal dodacahedron), which has attached to it in regular alternation, at the extremities of the assumed axes, small crystals of the same form.

Diversity of crystallized forms is one of the most obvious features of mineralogical occurrences, but examples are found in nature where differently formed crystals are encased within each other, pointing to a crystallographic identity. In Fig. 8 such an instance is shown, a *scalenohedron* of calcite, supporting at its apex a *rhombohedron* of the same mineral, the two enclosed in a larger crystal of calcite made up of a hexagonal prism and a rhombohedron; and geometrical analysis shows that the scalenohedron, the

rhombohedron and the prism are referable to one crystal system. In Crystals an intensity of cohesion, of hardness, etc., is discovered in certain directions; the action of light, the electric reactions, the rate of decay, is dissimilar in different directions, and similar in others, and the inference in unavoidable that crystals are molecularly arranged with regard to fixed directions. These directions are called axes.
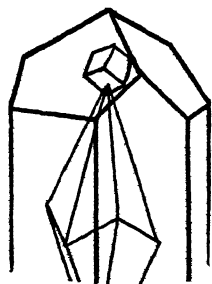
In undertaking to reach primitive or parent forms of crystals it is clear at the outset that they include prisms and pyramids, that

Fig. 8

these can have bases that are squares, or rhomboids, or even polygonal (many sided) that the prisms and pyramids can be erect or inclined. Furthermore in the investigation of crystallized minerals, by developing forms through cleavage, minerals are found which give *dodecahedral* forms (Pl. 1, Fig. 36). By this method of inquiry some thirteen parent forms at first appeared to underlie the possible number of derivative crystals; eight prisms with four-sided bases, five erect, three inclined; a six-sided erect prism; three octahedrons; and a dodecahedron. But the method of cleavage revealed

the fact also that forms like the cube, the equal-sided octahedron, and the dodecahedron, are related; that the same minerals yield them, and that upon an assumption of three equal and rectangular axes they could be brought together under one crystallographic definition, and with them a new number of derivative forms. Further reflection and observation made it apparent that *all* crystals could be referred to six systems, which were separated by the relations of certain directions, called axes, which axes formed the structural basis of these systems. These axes were lines of force, of accretion, and were symptomatic of a deeper molecular orientation in the ultimate particles of the crystal. Fig. 6 shows an incomplete crystal of silver in which along the direction of three lines, at right angles to each other, there has been a development of small octahedrons. The rest of the crystal is not filled out, but the nucleal axes of a larger octahedron are thus defined. Cuprite crystals (as Fig. 9) not infrequently are hollow faced, and the crystallizing oxide of
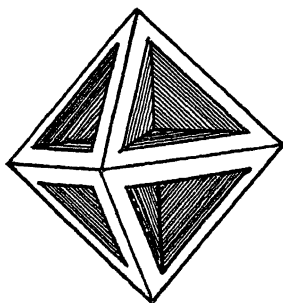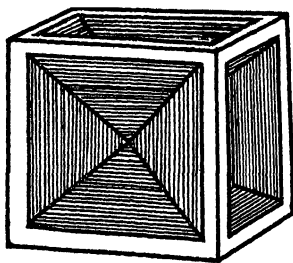

Fig. 9   Fig. 10

copper gathers along its outlines and at the extremities of the axes, which are the lines of crystallizing direction. Also in the hollow faced cube (Fig. 10) an example of salt (Halite), there is shown the accretion of material along its outlines, or conspicuously at its angles, which might be regarded as the ends of three assumed axes, which are at right angles to each other, and of equal length. These are significant indications of the existence of axial constants which, as imaginary lines, intersected by the faces of the crystal, form a geometrical system for the growth or construction of all crystals. Such evidence is further reinforced by the regular manner in which impurities or inclusions are found in natural crystals. Thus in calcite, impurities or foreign substances, in the form of pyrite, the sulphide of Iron, are found as inclusions in symmetrical positions
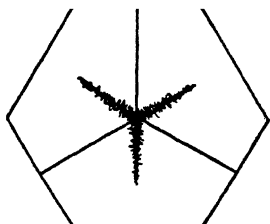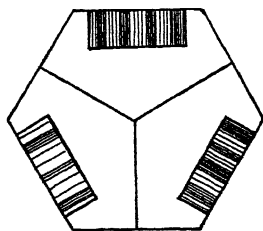
Fig. 11

Fig. 12

with relation to the axes (Figs. 11, 12). Again Calcite from Modum in Norway encloses needles of göthite arranged parallel to the axes of the crystal. In Nephelite, occur green leaves of hornblende which are governed in their arrangement by an obvious axial alignment, and Leucite, a mineral in volcanic rocks, frequently holds inclusions (*Augite, Magnetite*) which in a cross section of the mineral, are seen to be either grouped in a central mass or distributed in concentric circles. In view of all these considerations greatly reinforced by a study of optical properties, of the pittings or luster of faces, of unequal solubility in different directions of minerals, etc., etc., the theory of axial formation in crystallized minerals was firmly established. Let us consider now the systems as now generally recognized. There are six such systems, with a quite sharply separated section (the Rhombohedral) in one (the Hexagonal), and in all except the sixth, which has four, there are three axes.

Besides the Isometric System, in which the three axes are all equal and at right angles to each other, there is the **Tetragonal System** in which the three axes are at right angles, two are equal and the third unequal; the **Orthorhombic System** in which the three axes are at right angles and are all unequal; the **Monoclinic System** in which the axes are all unequal and one axis is inclined to the vertical axis which is at right angles to the third; the **Triclinic System** in which the three axes are all unequal and inclined to each other; and the **Hexagonal System** in which there are three equal, horizontal axes in one plane, making angles of 60° with each other, while the fourth axis (vertical) is at right angles to these horizontal axes and is unequal in length. These six systems and their illustration are now briefly undertaken.

RESUMÉ

All three axes at right angles.

Isometric, Three Axes of equal lengths.
Tetragonal, Two Axes of equal lengths.
Orthorhombic, Three Axes of unequal lengths.

One axis inclined; two at right angles.

Axes unequal.
Monoclinic.

Three axes inclined; axes unequal.

Triclinic.

Three axes in same plane making 60° with each other; equal
in length. *One, vertical axis, at right angles to the other three.*

Hexagonal.

Whole Forms (Holohedrism) and Half Forms (Hemihedrism).
Before the systems of crystals are considered, it is necessary to
understand the very important distinction between crystals with
all their normal faces developed and crystals with only half of their
normal faces developed. This has been already alluded to, but now
will be more fully discussed. The phase of hemihedrism is per-
haps most clearly illustrated in the crystals of the First (Isometric)
system and the following figures show the relation of the whole
to the half forms. Hemihedrism arises from the suppression of
alternate faces or groups of faces, and the extension of the re-
maining faces or groups of faces, until they meet and enclose a
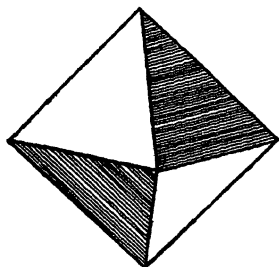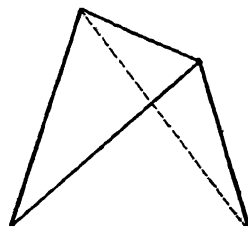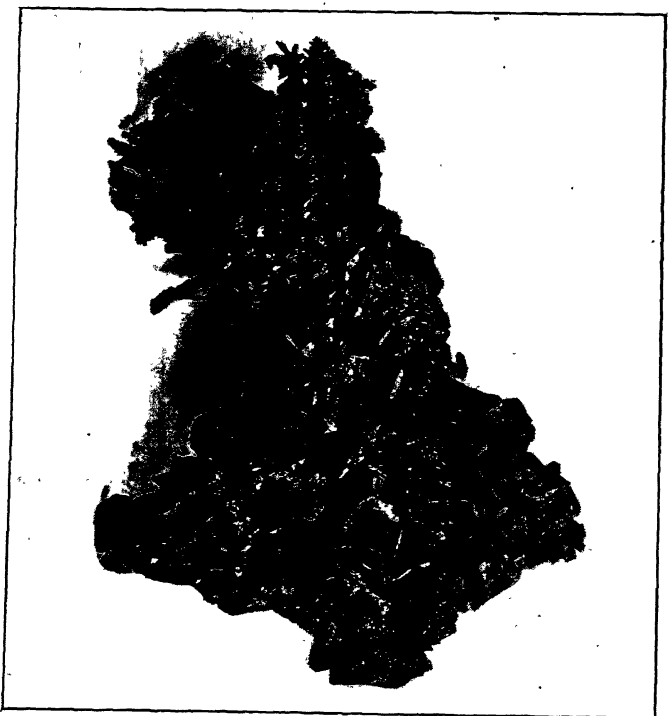

Fig. 13

Fig. 14

solid, thus forming a crystal. In the example (Fig. 13) the octa-
hedron has alternate plain and lined faces. Remove the lined faces

SILVER
Kongsberg, Norway
Bement Collection, American Museum of Natural History

COPPER
Central Mine, Keweenaw, Mich.
Bement Collection, American Museum of Natural History

and Fig. 14 results, from the development of the plain faces, remove the plain faces and Fig. 15 results from the similar development of the lined faces, and two (right and left) tetrahedrons take the
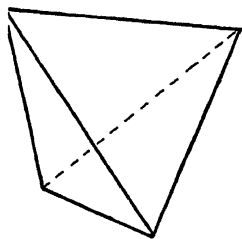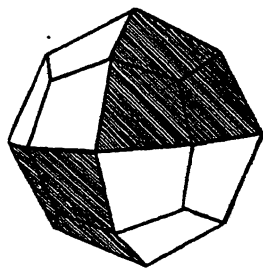

Fig. 15

Fig. 16

place of the original octahedron. The axes of the octahedron which terminated in its solid angles, in the tetrahedrons meet the middle of the opposite edges.

Again take the Tetragonal-trisoctahedron (Fig. 16) and remove the alternate groups of unshaded and shaded faces and the two respectively right and left (positive and negative) hemihedral forms are produced, shown by Figs. 17 and 18, sometimes called tris-dodecahedrons, in which the axes of the full form also meet the centers of the straight edges. These tris-dodecahedrons are ob-
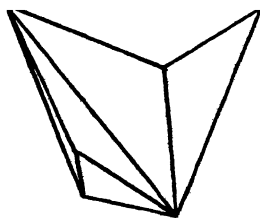

Fig. 17
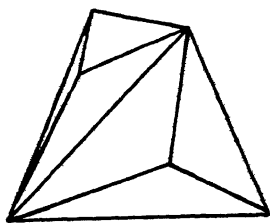
Fig. 18

viously tetrahedrons with the single planes of the tetrahedrons replaced by three triangular faces.

Again take the Trigonal trisoctahedron (Fig. 19) and remove the alternate groups of faces, (observe these groups are the an-alogues of the single alternate face in the octahedron) and, from the respective development of the unshaded and shaded faces, there

Fig. 19   Fig. 20   Fig. 21

arises Figs. 20 and 21, or a right and left deltoid dodecahedron, in which however, the previous triangular faces become four-sided faces.
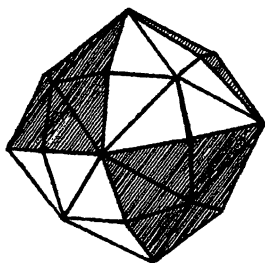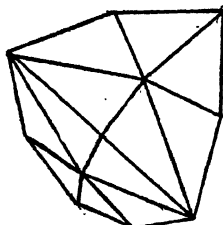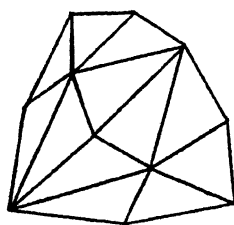
Fig. 22   Fig. 23   Fig. 24

Similarly Figs. 22, 23, and 24, show the hemihedral forms, and their formation, of the Hexoctahedron.
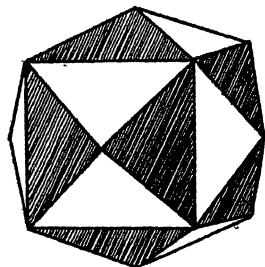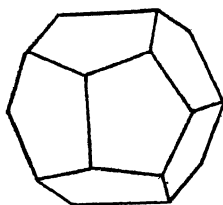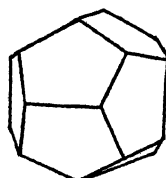
Fig. 25   Fig. 26   Fig. 27

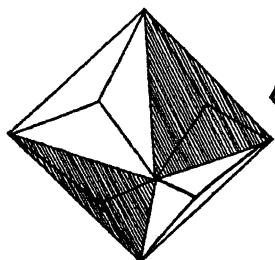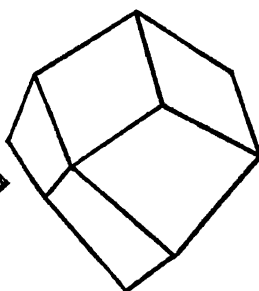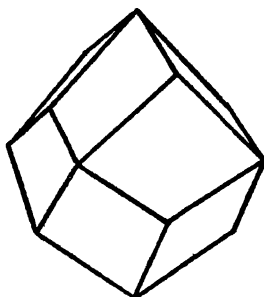Hemihedrism produces more complex results in the Tetrahexa-hedron, where (as shown in Fig. 25) the alternate faces (shaded and unshaded in figures) when developed, produce the pentagonal dodecahedron, Figs. 26, 27.

Similarly alternate faces in the hexoctahedron quadrants (previously taken away in alternate groups) shown, in shaded and unshaded, in Fig. 28, produce the diplohedral forms of Figs. 29 and 30.
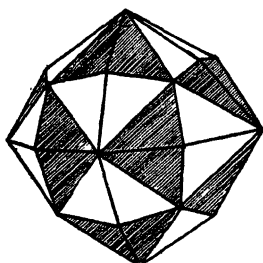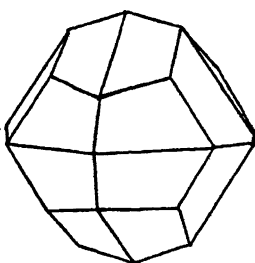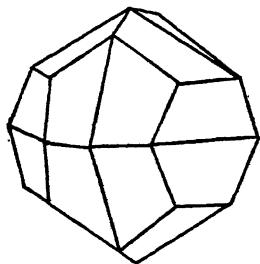
Fig. 28   Fig. 29   Fig. 30

The hexoctahedron submits to a still different phase of hemihedrism—the plagihedral—which is illustrated in Figs. 31, 32, 33. (Compare and note differences with Figs. 28, 29, 30).
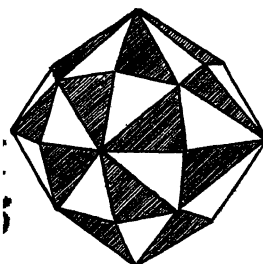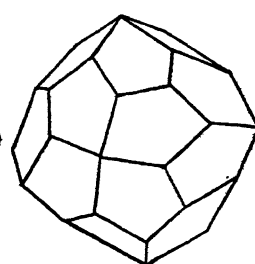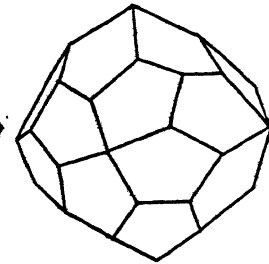
Fig. 31   Fig. 32   Fig. 33

THE SIX SYSTEMS OF CRYSTALS

THE ISOMETRIC SYSTEM,
Three Axes Equal and at Right Angles.

In this system there are seven *whole* (holohedral) forms which are formed by planes meeting these equal axes at such inclinations

and in such numbers as to create these very distinctive crystals. These forms are: 1, *Cube* (Fig. 34) ; 2, *Octahedron* (Fig. 35) ; 3, *Dodecahedron* (Fig. 36) ; 4, *Tetrahexahedron* (Fig. 52) ; 5, *Trigonal Trisoctahedron* (Fig. 60) ; 6, *Tetragonal Trisoctahedron* (Fig. 44) ; 7, *Hexoctahedron* (Fig. 62). Besides these there are a series of half (hemihedral) forms in which half of the planes of the whole form, in symmetrical alternation, have been removed and a group of crystals result which present a strikingly different appearance. Simple forms may be combined (see Plates 1 and 2).

1. **Tetrahedron,** the geometric half of an octahedron, viz, an octahedron with two alternating faces above the medial plane and two alternate faces below the medial plane removed and the remaining faces produced (Fig. 66).

2. **Hemi Trigonal Trisoctahedron,** the result of similarly removing the alternating sets of three planes from a trigonal trisoctahedron (Fig. 77).

3. **Hemi Tetragonal Trisoctahedron.** A tetragonal trisoctahedron similarly treated (Fig. 75).

4. **Hemi Hexoctahedron** (Figs. 76 and 79), Fig. 79 being formed by removing the alternate sets of six faces in a hexoctahedron, and Fig. 76 resulting from removing the alternate faces in each set.

5. **Hemi Tetrahexahedron,** or sometimes **Pyritohedron,** from its characteristic appearance in Pyrite; also called **Pentagonal Dodecahedron.**

One-fourth of the faces only may be retained when **Tetartohedral** forms result.

Tetartohedral forms may be produced from the hemihedral forms of the hexoctahedron by halving, though in a number of the whole forms of the Isometric System the process brings to view only hemihedral phases.

Tetartohedral crystals occur in nature in artificial crystals of
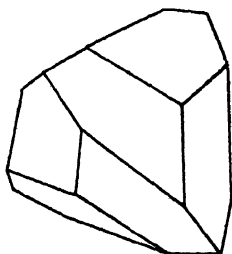
Fig. 88a
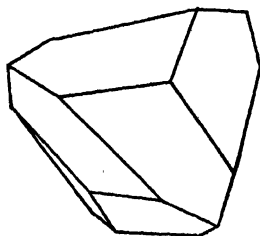
Fig. 88b

NATIVE COPPER CRYSTALS
Lk. Superior, Mich.
Bement Collection, American Museum of Natural History
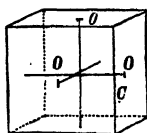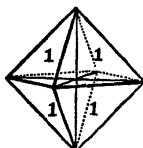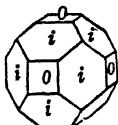
Fig. 34   Fig. 35   Fig. 36   Fig. 37   Fig. 38
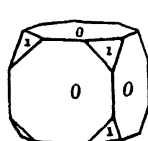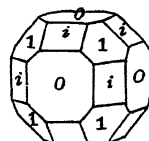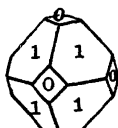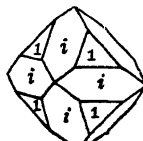
Fig. 39   Fig. 40   Fig. 41   Fig. 42   Fig. 43
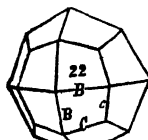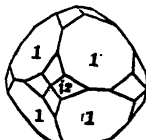
Fig. 44   Fig. 45   Fig. 46   Fig. 47   Fig. 48
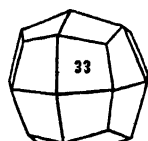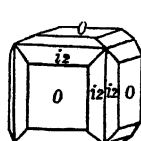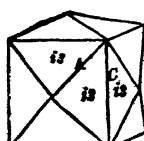
Fig. 49   Fig. 50   Fig. 51   Fig. 52   Fig. 53
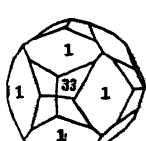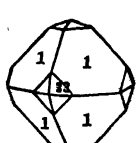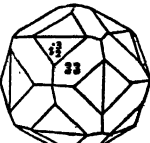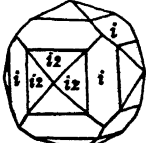
Fig. 54   Fig. 55   Fig. 56   Fig. 57   Fig. 58
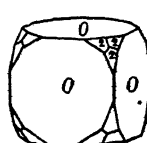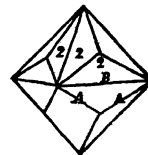
Fig. 59   Fig. 60   Fig. 61   Fig. 62   Fig. 63

PLATE 1
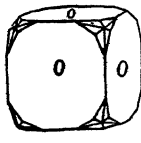
Chloride of Sodium, and the Nitrate of Strontium, Barium, and Lead. Here occurs the tetrohedral pentagonal dodecahedron (Figs. 88 a and b) which is the halved or tetrahedral form of the gyroid. Dr. Wulff, who studied the crystals of barium nitrate, observes that when crystals are deposited from pure aqueous solutions the cube predominates modified by these tetartohedral forms. When sodium nitrate was present, crystals were deposited which resemble regular octahedra, with these faces again, and in solutions containing also potassium nitrate and sugar, still more complicated crystals arose.

EXPLANATION OF PLATE 1.

Fig. 34, cube; Fig. 35, octahedron; Fig. 36, rhombic-dodecahedron; Fig. 37, cube and rhombic-dodecahedron; Fig. 38, cube and rhombic-dodecahedron; Fig. 39, cube and octahedron; Fig. 40, cube, octahedron, and rhombic-dodecahedron; Fig. 41, cube and octahedron; Fig. 42, octahedron and rhombic-dodecahedron; Fig. 43, cube and tetragonal-trisoctahedron; Fig. 44, tetragonal-trisoctahedron; Fig. 45, cube and tetragonal-trisoctahedron; Fig. 46, octahedron and tetra-hexahedron; Fig. 47, tetragonal-trisoctahedron and rhombic-dodecahedron; Fig. 48, rhombic-dodecahedron and tetragonal-trisoctahedron; Fig. 49, tetragonal-trisoctahedron; Fig. 50, cube and tetra-hexahedron; Fig. 51, tetra-hexahedron; Fig. 52, tetra-hexahedron; Fig. 53, rhombic-dodecahedron and tetragonal-trisoctahedron; Fig. 54, octahedron and tetragonal-trisoctahedron; Fig. 55, tetra-hexahedron and tetragonal-trisoctahedron; Fig. 56, rhombic-dodecahedron and tetra-hexahedron; Fig. 57, octahedron and tetragonal-trisoctahedron; Fig. 58, cube and trigonal-trisoctahedron; Fig. 59, octahedron and trigonal-trisoctahedron; Fig. 60, trigonal-trisoctahedron; Fig. 61, cube and hexoctahedron; Fig. 62 hexoctahedron; Fig. 63, octahedron and hexoctahedron.

In Plate 1 are given a series of *combinations* of primary forms in the Isometric System, wherein the modification of one form by another is clearly shown. In most cases there is a predominant form which is conjoined with a subordinate form and only sensibly altered in outline by the secondary faces; as in Fig. 39 the cube is predominant and the truncating faces of the octahedron (at the angles) subordinate. Much complexity may result from the combination of many simple forms and in natural crystals such elaboration is not infrequent.

In Plate 2 combinations of whole (holohedral) and half (hemihedral) are variously illustrated.
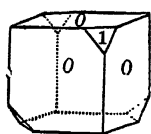
Fig. 64
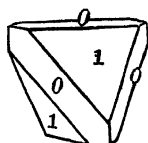
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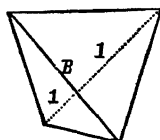
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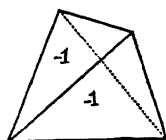
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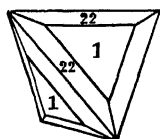
Fig. 68

Fig. 69
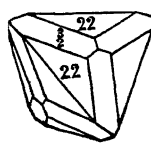
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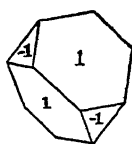
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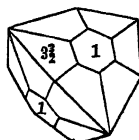
Fig. 72
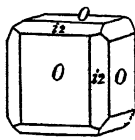
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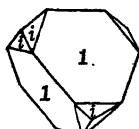
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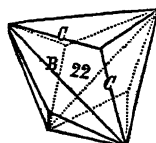
Fig. 75

Fig. 76
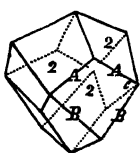
Fig. 77

Fig. 78
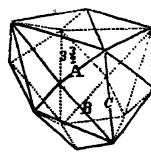
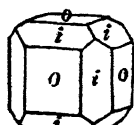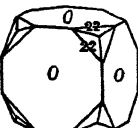Fig. 79
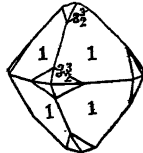
Fig. 80
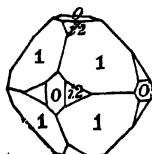
Fig. 81
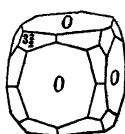
Fig. 82

Fig. 83
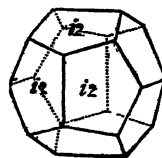
Fig. 84
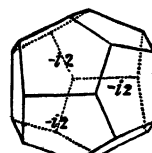
Fig. 85

Fig. 86

Fig. 87

Fig. 88

PLATE 2
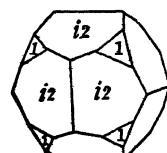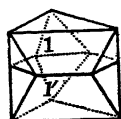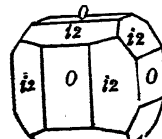
In the trigonal-trisoctahedron a face cuts two axes at the same distance (the octahedral distance) from the origin, and the third at m distance.

In the tetragonal trisoctahedron a face cuts one axis at the octahedral distance and the other two at m distance.

In the hexoctahedron a face cuts one axis at the octahedral distance and the other two at m and n distances.

There is no principal axis in the Isometric system, the axes all being equal, and the crystal identical, whatever axis is put in a vertical position. It is the system with the highest symmetry (see p. 49), and the octahedron, cube, and rhombic dodecahedron are its basic forms, and invariable; they are the limital (*grenzformen*) forms of the others which are variable and can pass into these, as the trigonal trisoctahedron into the octahedron and rhombic dodecahedron, the tetragonal trisoctahedron into the octahedron and the cube, the tetrahexahedron into the rhombic dodecahedron and the cube.

The hexoctahedron of forty-eight faces may be so modified in the values of m and n (see formulæ) as to yield all the other six holohedral forms. (Note: The student should be required to mould the crystals from putty or modelling clay and modify some initial simple form as the cube until he develops all the rest. If through such a cube three wires are passed at right angles, and extending beyond its faces, he can, with a card or paper, determine for himself the ratio and relations of the "intercepts," viz, the points where the faces cut the axes).

THE TETRAGONAL SYSTEM.

Three Axes, Two Equal, the Vertical Unequal, all at Right Angles.

In this system we have prisms and pyramids, and the basal planes of prisms. The prisms may be four-sided (tetragonal) or eight-sided (ditetragonal) as also the pyramids, the ditetragonal pyramid being also called **Zirconoids**. In the tetragonal prisms there are distinguished unit prisms when the axes intersect the edges of the prisms and diametral prisms when they intersect the faces, and the same distinction is made in the pyramids.*

---

*There is also a prism and pyramid of the third order wherein the axes cut the planes at unequal distances from the edges. Illustrated in Scheelite.

1. Tetragonal prism, unit prism, Fig. 89.
2. Tetragonal prism, diametral prism, Fig. 90.
3. Ditetragonal prism, Fig. 91.
4. Tetragonal pyramid, unit pyramid, Fig. 92.
5. Tetragonal pyramid, diametral pyramid, Fig. 93.
6. Ditetragonal pyramid, zirconoid, Fig. 94.

There are in the tetragonal system, as in the isometric, hemi-hedral forms, which are, in the case of the tetragonal pyramid, called **Sphenoids,** and in the case of the ditetragonal pyramid, **Scalenohedrons** and **Trapezohedrons.** (Compare hexagonal system).

Fig. 89   Fig. 90   Fig. 91
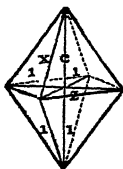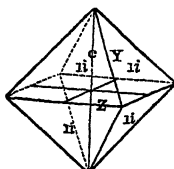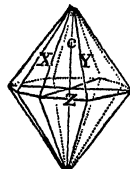
Fig. 92   Fig. 93   Fig. 94

PLATE 8

These hemihedral forms arise, as in the isometric system, from the selection of alternate faces, or pairs of faces, or, in other words, the halving of the faces. The isometric octahedron thus treated yielded a right and left tetrahedron, the tetragonal pyramid yields a right and left *sphenoid* which resembles a tetrahedron, but is obviously elongate. And here too the axes cut the edges. It is quite plain that the position of the axes in these derivative sphenoids will vary, as a pyramid of the first or second order is chosen for halving. (Figs. 95, 96, 97).
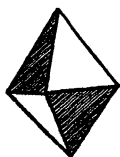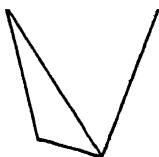
Fig. 95   Fig. 96   Fig. 97

Again taking a ditetragonal pyramid, or one with sixteen faces, eight above and eight below the median plane, and removing the faces above and below in alternate order, a *trapezohedron* is obtained (Figs. 98, 99, 100) ; while removing these faces in alternate
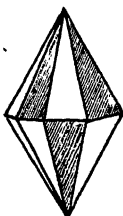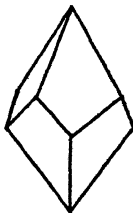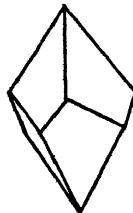
Fig. 98   Fig. 99   Fig. 100

pairs the corresponding scalenohedrons result (Figs. 101, 102, 103), having a zigzag base.
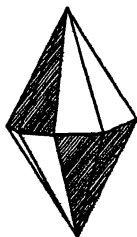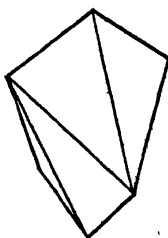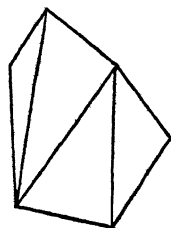
Fig. 101   Fig. 102   Fig. 103

A pyramid or prism of the third order may be formed from a ditetragonal pyramid or prism; in it the axes cut the edges of the crystal unequally (Fig. 104).
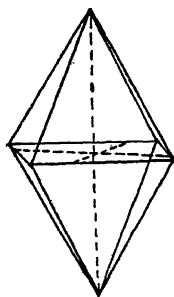
Fig. 104

Formulae of the Tetragonal crystals.

Basal plane (pinacoid) ....O P
Pyramid (first order) ....m P
Pyramid (second order) ....m P ∞
Ditetragonal pyramid ....m P n
Prism (first order) ....∞ P
Prism (second order) ....∞ P ∞
Ditetragonal prism ....∞ P n

In these symbols P represents a primary pyramid, and m P a pyramid greater or smaller according to the value of m, usually ½ P, 2 P, or 3 P. This is a pyramid of the so-called first order, with the axes terminating in the angles of the pyramid. m P ∞ then represents a pyramid of the same size but of the second order, with the axes terminating in the center of the horizontal edges or with each face parallel to one horizontal axis, and *never* intercepting it, or at infinity ∞. m P n shows a ditetragonal pyramid (eight-faced pyramid, above and below) whose faces cut one of the horizontal axes at n distance from the origin. When m becomes infinity it is obvious that the face of the pyramid becomes parallel to the vertical axis or the pyramid becomes a prism and ∞ P is such a prismatic symbol. As can be understood from the explanation of the second order pyramid, ∞ P ∞ represents the second order prism, each face of which is not only parallel to the vertical axis (principal) but also to one of the horizontal axes, viz, touching it at ∞. Then in the ditetragonal prism the faces cut a horizontal axis at n distance.

Combinations of Tetragonal Forms.

Plate 4 shows combinations of pyramids and prisms.

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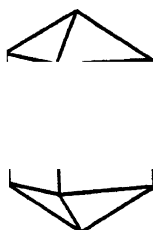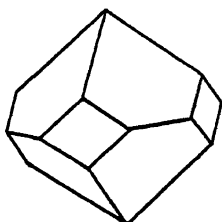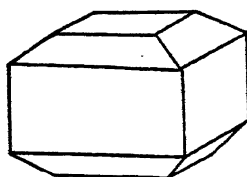
Fig. 105 Fig. 106 Fig. 107 Fig. 108
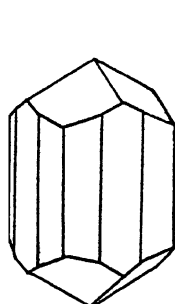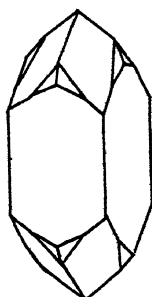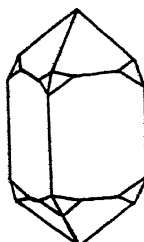
Fig. 109 Fig. 110 Fig. 111 Fig. 112
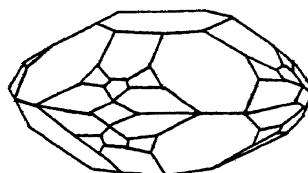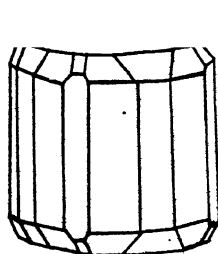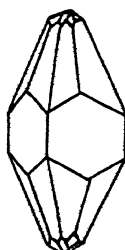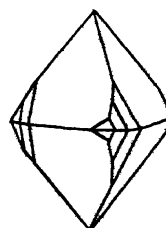
Fig. 113 Fig. 114 Fig. 115 Fig. 116
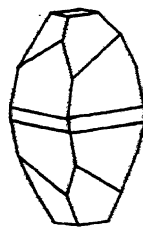
PLATE 4

EXPLANATION OF PLATE 4.

Fig. 105, Tetragonal pyramid and prism; Fig. 106, Tetragonal pyramid and prism (predominant development of the pyramid); Fig. 107, Prism, pyramid and basal pinacoid; Fig. 108, Pyramid and

prism and basal pinacoid; Fig. 109, Pyramid and tetragonal and di
tetragonal prism; Fig. 110, Pyramid, ditetragonal pyramid an
prism; Fig. 111, Pyramids (first order and ditetragonal) and prisn
of first order; Fig. 112, Pinacoid, five pyramids and prism (firs
and second order and two ditetragonal); Fig. 113, Pinacoid, prism
and pyramids (let pupil distinguish these); Fig. 114, Two apica
pyramids, ditetragonal pyramid and prism; Fig. 115, Four pyra-
mids, first, second, and third orders (crystal of Scheelite); Fig.
116, Prism, pyramid and pyramid of the third order (crystal of
Fergusonite).

The term Pinacoid used, in the description of this system, for
the first time, means a plane of a crystal which cuts one axis and
is *always* parallel to the other two. It appears frequently in the
succeeding systems. It is derived from two Greek words meaning
like a plank or board. (Note: The pupil should be required to
draw on the blackboard or on paper *enlarged* copies of the figures
given here for the Tetragonal and other systems, and explain their
elements. He then from memory should compose combinations from
simple forms. These figures thus made, cannot be expected to have
geometrical symmetry, but the exercise will prove wonderfully
helpful in fixing the nature and development of crystals and their
combinations).

THE ORTHORHOMBIC SYSTEM.

Three Axes all Unequal and at Right Angles to Each Other.

In this system the axes are separated by names; the vertical
axis, the macrodiagonal or long horizontal axis; the brachydiagonal
or short horizontal axis. The forms consist of prisms and pyramids,
and these are separated into *macro* and *brachy* forms as they are
built upon the *macro* or *brachy diagonal.* Vertical planes cutting
one axis and parallel to the other two are called *macro* or *brachy
pinacoids,* according as they are parallel to the long or short lateral
axis, and inclined planes cutting two axes (vertical and horizontal)
and parallel to the third, are known by the name of the axes to
which they are parallel, being called *brachy* or *macro domes.* There
may also be hemihedral forms in this system.

This system is a simple one, and yields but few forms. A
section of a prism or the medial plane of a pyramid is a rhomb,
not a square, as in the Tetragonal system. In this system the stu-
lent meets the new forms of pinacoids and domes. In Figs. 117-
:20 are given illustrations of the orthorhombic pyramid, prism,
:nd *domes,* the pinacoids being planes parallel to the different

axes, the *basal* forming the top and base of a prism, the *macro* pinacoid a face parallel to the longer horizontal axis, and the *brachy* a face parallel to the shorter horizontal axis. Inclining such faces above and below the horizontal plane towards the vertical axis they become inclined faces parallel to the horizontal axes from which they are named, viz, *macro* or *brachy* domes. A pinacoid cuts one axis *only*, and is parallel to the other two, a *dome* cuts two axes *only* and is parallel to the third.
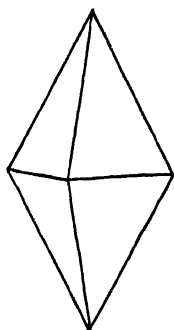
Fig. 119
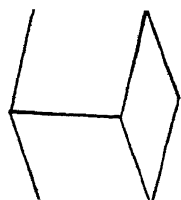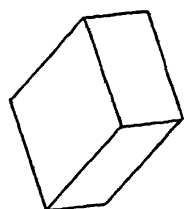
Fig. 117   Fig. 118   Fig. 120

   The derivation of the macro and brachy pyramids and prisms from the ground or primary or unit pyramid or prism, is made as follows: lengthen the macro-diagonal (long axis) some exact distance (with reference to the original length of the unit pyramid, viz, twice or three times or half as long again) without changing the brachy diagonal (short axis) and then form the pyramid on these reconstituted axes and a macropyramid results. Similarly with the brachy diagonal, the macro diagonal remaining unchanged, a brachy pyramid is formed. Now it is evident that if such a distance becomes infinity (∞) then in the first instance a *macro dome* replaces the macro pyramid, and in the second a *brachy dome* replaces the brachy pyramid.
   In an identical manner brachy and macro prisms are formed from the unit prism. In the case of these prisms it is plain that if the point, at which their faces cut either axis, becomes infinity, then, according as a macro or brachy axis is involved, the prismatic face becomes a macro or brachy pinacoid.

Formulae of Orthorhombic crystals.

Basal plane (pinacoid) ....O P
Pyramid ....m P
Brachy pyramid ....$m \; \breve{P} \; n$
Macro pyramid ....$m \; \bar{P} \; n$
Brachy dome ....$m \; \breve{P} \; \infty$
Macro dome ....$m \; \bar{P} \; \infty$
Prism ....∞ P
Brachy prism ....$\infty \; \breve{P} \; n$
Macro prism ....$\infty \; \bar{P} \; n$
Brachy pinacoid ....$\infty \; \breve{P} \; \infty$
Macro pinacoid ....$\infty \; \bar{P} \; \infty$

The unit or "ground" pyramid P when given a greater or less vertical extension than 1 becomes m P, in which with the unit base the vertical axis becomes once, twice, one-half, etc., the unit length. When the brachy diagonal (short axis) is increased n times (always greater than 1) or the faces of m P cut the brachy diagonal at n distance from the origin, the formula for this pyramid is $m \; \breve{P} \; n$. Obviously the same procedure with the macro diagonal (long axis) gives $m \; \bar{P} \; n$, the axes being indicated by $-$ and $\smile$.

Again the prism is ∞ P, which is the limit form of the pyramid, or m becomes infinity which means that the prismatic faces are parallel to the vertical axis. This orthorhombic prism then is either brachy or macro-prismatic by the introduction of the variable n which reckoned on the brachy or macro diagonal gives rise to the respective prisms $\infty \; \breve{P} \; n$ and $\infty \; \bar{P} \; n$.

The pinacoidal formulæ are self-evident, as faces which are the limital expression of a prismatic face, or n becomes ∞, with reference, according to the pinacoid considered, to the brachy or macro diagonal.

Combinations of Orthorhombic Forms.

Plate 5 illustrates the union in single crystals of the orthorhombic forms just reviewed.

EXPLANATION OF PLATE 5.

Fig. 121, Two prisms and pyramid (topaz); Fig. 122, Prisms, pyramid and dome (ilvait); Fig. 123, Basal brachy and macro pinacoid; Fig. 124, Two pyramids of different inclinations, dome, and basal pinacoid (sulphur); Fig. 125, Basal pinacoid, and domes; Fig. 126, Basal pinacoid and domes; Fig. 127, Basal pinacoid, prisms, and domes (the last three are *barite*); Fig. 128, Three pinacoids,
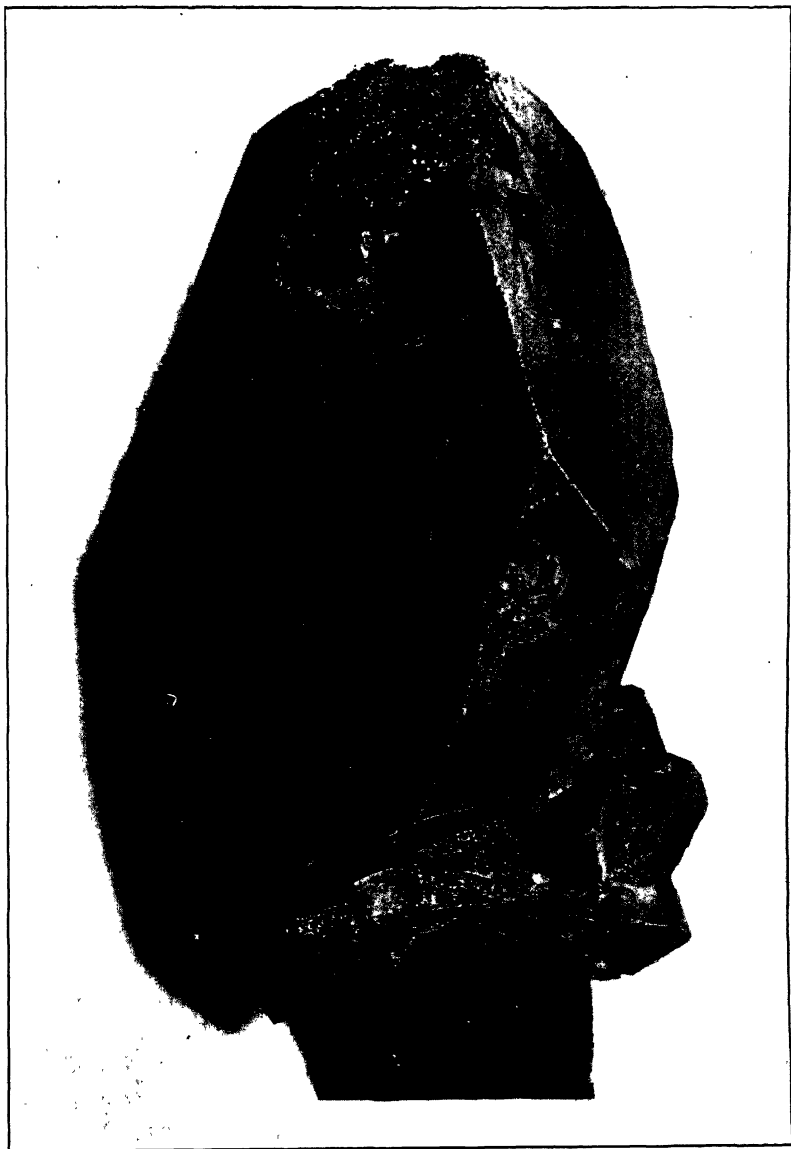
GALENA
Galena, Ills.
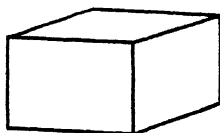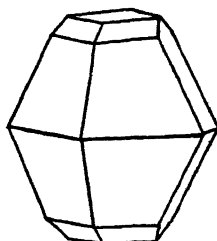
Fig 121   Fig. 122   Fig. 123   Fig. 124
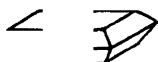
Fig. 125
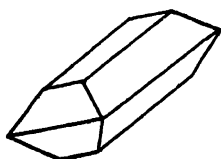
Fig. 126
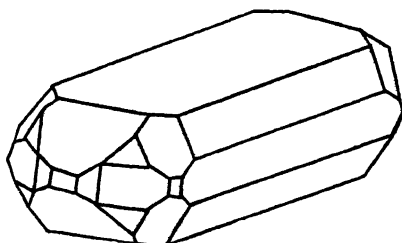
Fig. 128

Fig. 127

Fig. 129   Fig. 130   Fig. 131

PLATE 5
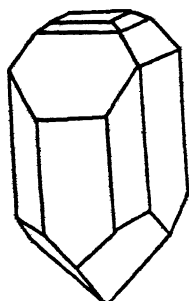
two domes, two pyramids, three prisms; Fig. 129, Prism, two hemi-pyramids (rhombic sphenoids); Fig. 130, Prism, two hemi pyramids (the half faces in this last case have become equally developed making an orthorhombic pyramid.) (Epsom Salt and Sulphate of Zinc); Fig. 131, a hemimorphic crystal; viz, the opposite poles of the crystal show different faces.

Hemihedrism shown in the Isometric and Tetragonal systems occurs in the Orthorhombic. Sphenoids are produced by the suppression of alternate faces of the pyramid as in the tetragonal system, and the right and left tetrahedrons thus produced are shown
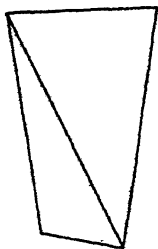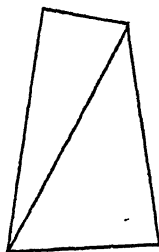
Fig. 132   Fig. 133

in Figs. 132, 133. This hemihedrism could be still further developed by the suppression of opposite halves of the domes, but it is evident such hemihedrism would not form a closed crystal and such hemihedral faces would appear only on prisms and pyramids. Hemihedrism of this system is well shown in crystals of tartar-emetic (*potassium-antimonyl dextro tartrate*). (Note: The pupils previously acquainted with making crystal models in modeling wax or clay, or in drawing crystals on paper or blackboards, will now *cut out* orthorhombic crystals from paper, pasting the paper edges together, and forming prisms and pyramids. The edges of these they can then truncate with domes and pinacoids).

THE MONOCLINIC SYSTEM.

Three Unequal Axes, Two Horizontal Axes at Right Angles to Each Other, but One the Clino Axis Inclined to the Vertical Axis.

In this system the axes are separated by names, as in the orthorhombic, the vertical axis, the clino-axis or inclined, the ortho axis or horizontal. The forms consist of prisms and pyramids and

these are distinguished as *ortho* and *clino* as they are formed upon the ortho or clino axis. Vertical planes cutting one axis and parallel to the other two are called *ortho* or *clino pinacoids,* according to the axis they are parallel to, viz, the horizontal or the inclined; and inclined planes cutting two axes (vertical and one lateral) and parallel to the third, are known by the name of the axis to which they are parallel, being called *ortho* or *clino domes.* The terminal plane of a prism is called the *basal pinacoid.* Hemihedral forms may occur in this system, and tetartohedral forms are possible.

In Figs. 134 to 138 illustrations are given of a monoclinic pyramid (Figs. 134, 135), and a monoclinic prism (Fig. 136), with an example of a clino dome (Fig. 137), and an ortho dome (Fig. 138), while also, in these last three forms, the basal, ortho, and clino pinacoids are shown in the terminal planes on which the axes are delineated, respectively.
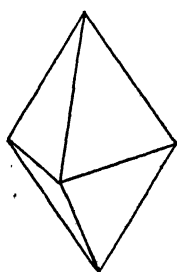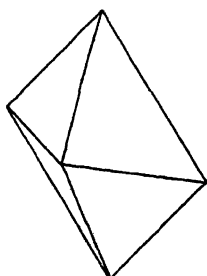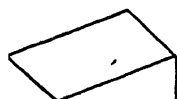

Fig. 134   Fig. 135   Fig. 136
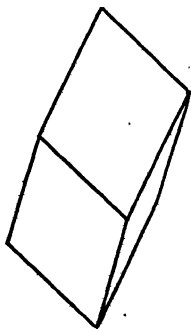
Fig. 137   Fig. 138   Fig. 138 (bis.)

It will be observed at once that while the Monoclinic system resembles the Orthorhombic the inclined axis causes a sharp contrast,—the angles made at the intersection of the vertical and inclined axes are unequal, or acute and obtuse, thus differing from the right angle (90°) formed at the same point in orthorhombic crystals. And the two pyramidal faces subtending(?) or enclosing the acute angle above and below the pyramidal base, and the two in the same opposite positions enclosing the obtuse angle are considered as *hemi pyramids*. These are considered independent, and in nature are observed as separate occurrences on natural crystals. The former is a positive, the latter a negative hemi pyramid. Again in Figs. 136, 137, and 138, it is readily seen that in the prism and in the clino dome the faces are all equivalent, but that in Fig. 138 the faces of the ortho dome are quite unequal. The opposite pairs of faces thus made are called *hemi domes*. These are found in nature. It is obvious that the completed clino and orthodome form inclined prisms.

Formulae of Monoclinic crystals.

The monoclinic pyramid is made up of the positive and negative *hemi pyramids* and therefore the sign of the unit or primary pyramid becomes $\pm$ P, and similarly the orthodome prism is made up of two hemi domes, one positive, the other negative, hence its sign becomes $\pm m$ P ∞, but that the faces of the clino-dome being identical in space need not be thus distinguished. Otherwise the derivation of the monoclinic formulæ follows the steps given under the orthorhombic. The pyramid $\pm m$ P becomes an orthopyramid by multiplying the orthodiagonal by any number n and similarly a clino pyramid, the distinction in the sign being indicated by a straight or an inclined line. As n becomes ∞ ortho or clino domes are formed. Again from the prism ∞ P ortho or clino prisms arise by multiplying the ortho or clino diagonal by n and such prisms become ortho or clino pinacoids as n becomes ∞. Half forms in minerals, crystallizing in this system, obviously constantly occur.

Basal Pinacoid ....O P
Monoclinic pyramid ....$\pm m$ P
Ortho-pyramid ....$\pm m$ P̄ n
Clino-pyramid ....$\pm m$ Ṕ n
Ortho-dome ....$\pm m$ P̄ ∞
Clino-dome ....m Ṕ ∞
Monoclinic Prism ....∞ P
Ortho-prism ....∞ P̄ n
Clino-prism ....∞ Ṕ n
Ortho-pinacoid ....∞ P̄ ∞
Clino-pinacoid ....∞ Ṕ ∞
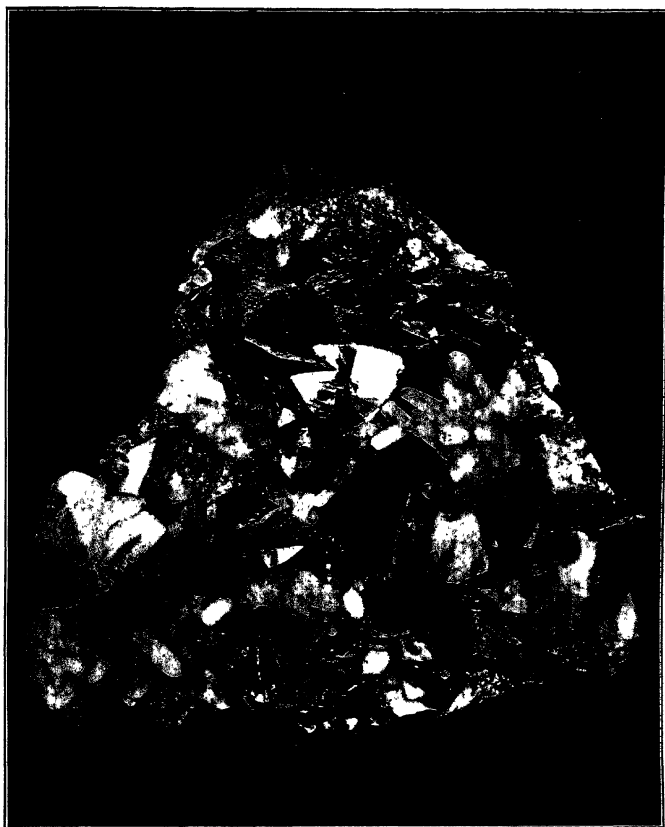
CHALCOPYRITE
Cornwall, England
Bement Collection, American Museum of Natural History

COMBINATIONS OF MONOCLINIC FORMS.

Plate 6 illustrates the combinations of monoclinic forms in single crystals.

EXPLANATION OF PLATE 6.

Fig. 139, Monoclinic pyramid and prism with clinopinacoid (gypsum); Fig. 140, A hemi-pyramid prism and clinopinacoid (gypsum); Fig. 141, Prism, orthopinacoid, clinopinacoid, hemi-pyramid (augite); Fig. 142, Prism, clino pinacoid, basal pinacoid, and hemi orthodome (orthoclase); Fig. 143, Prism, clinopinacoid, basal pinacoid, clino dome, hemi orthodome and hemi pyramid (orthoclase); Fig. 144, Two pinacoids, a prism (heulandite), and hemi domes.
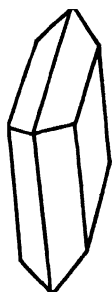
Fig. 140

Fig. 139
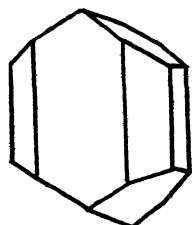
Fig. 141
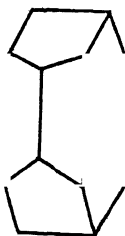
Fig. 142
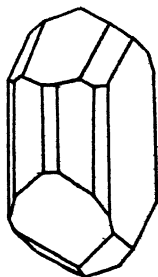
Fig. 143
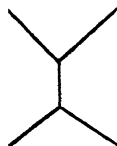
Fig. 144

PLATE 6

(Note: The exercise in the Monoclinic system should consist of tying together small wooden rods of unequal length, with varying inclinations and building the crystal forms out with paper, which,

according to the ingenuity and handiness of the pupil, may imitate the complexity of natural crystals. Drawings on paper and the board should also be required).

THE TRICLINIC SYSTEM.

Three Unequal Axes and all Inclined to Each Other.

In this system the axes are designated as vertical, macro-diagonal and brachy-diagonal, and the forms are prisms and pyramids, with pinacoids and domes.

The Triclinic system is the most irregular of all the systems, and contains in nature the smallest number of mineral species. The triclinic pyramid is regarded as made up of four partial (tetartohedral) pyramids, and the triclinic prism of two hemi prisms. The two faces of the tetartohedral pyramid are parallel to each other and lie above and below the equator of the united, "closed," pyramids. Such fourthlings are shown in Fig. 145. When the upright prism with its faces parallel to the vertical axis becomes inclined, with its faces parallel to the inclined axis, then the prism is a combination of hemi clino domes, which may be brachy or macro, as the prismatic faces are parallel to the short or long axis.

The signs of the crystal forms are derived as in the orthorhombic or monoclinic systems, the limit form of the prism being the pinacoid, and that of the pyramid the dome. $m\,\mathrm{P}$ is the general formula of the pyramid, and as it may be regarded as made up of four partial pyramids, Naumann has written it $m\,\mathrm{P}'$, $m\,'\mathrm{P}$, $m\,\mathrm{P}$, m, P. The general formulæ of the possible forms then become:

Basal Pinacoid ....O P
Pyramid ....$m\,'\mathrm{P}'$,
Macro pyramid ....$m\,'\mathrm{P}'\,n$
Brachy pyramid ....$m\,'\mathrm{P}'\,n$
Macro dome ....$m\,'\mathrm{P}'\,\infty$
Brachy dome ....$m\,'\mathrm{P}'\,\infty$
Prism ....$\infty\,'\mathrm{P}'$,
Macropinacoid ....$\infty\,\mathrm{P}\,\infty$
Brachypinacoid ....$\infty\,\mathrm{P}\,\infty$

The pyramids are separated into upper and lower Right, upper and lower Left, and the prism into Right and Left, the macrodome into Upper and Lower, the brachy dome into Right and Left.

Figs. 145, 146, 147 illustrate the difficult combinations of triclinic forms, and are interpreted in the following manner:

Fig. 145 P = basal pinacoid; m = brachy pinacoid; s the upper right tetartohedral pyramid; 1 = right hemi prism; T = left hemi prism; x = upper macrodome; (albite).
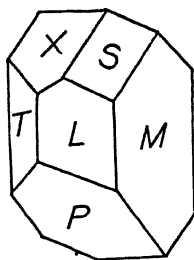
Fig. 145
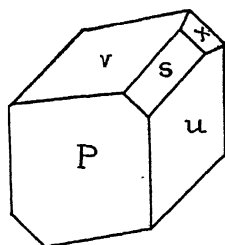
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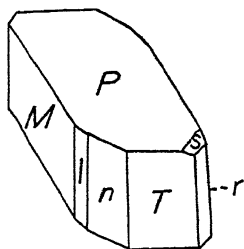
Fig. 147

Fig. 146 P = left hemi prism; u = right hemi prism; r = upper left tetartohedral pyramid; x = upper right tetartohedral pyramid; s = upper macrohemidome (axinite).

Fig. 147 M and T = left and right hemiprism; 1 = left macro-
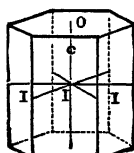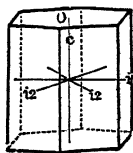
Fig. 148

Fig. 149
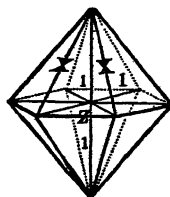
Fig. 150
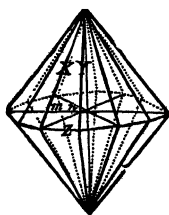
Fig. 151

Fig. 152

Fig. 153

PLATE 7
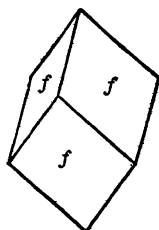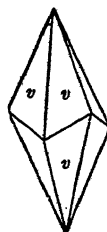
prism; n = macropinacoid; r = brachypinacoid; P = upper right tetartohedral pyramid; s = upper right tetartohedral brachypyramid (chalcanthite).

THE HEXAGONAL SYSTEM.

Three equal lateral axes inclined to each other in one plane at 60° and a vertical axis either longer or shorter at right angles to them.

In this system we have the *holohedral* (whole) forms and a series of *hemihedral* (half) forms which, from their geometric unity, number, and representation in nature, have been designated as the **Rhombohedral** system. The principal forms in the two subsystems are as follows:

Hexagonal prism, 1st series, Fig. 148.
Hexagonal prism, 2d series, Fig. 149.
Dihexagonal prism, or a prism with twelve faces.
Hexagonal pyramid, 1st series, Fig. 150.
Dihexagonal pyramid, Fig. 151.

The basal planes or pinacoids are the horizontal terminal planes of the prism.

THE RHOMBOHEDRAL SYSTEM.

Hemihedral.

Rhombohedron, formed by taking one-half of the faces of the hexagonal pyramid alternately above and below a medial plane. Fig. 152.

Scalenohedron, formed by taking one-half of the faces of the dihexagonal pyramid in alternate pairs above and below a medial plane. Fig. 153.

Trapezohedron, formed by taking one-half of the faces of the dihexagonal pyramid, alternately one above and one below a medial plane.

Trigonal prism, formed by taking alternately one-half of the faces of a hexagonal prism.

Tetartohedral forms are made by halving again the faces of the rhombohedral forms, and these appear in nature in quartz, cinnabar and phenacite.

The Hexagonal System presents very striking contrasts to the other systems. Its primary separation from the other systems is the four axes upon which its forms are constructed, and the second feature of interest is that three of these axes are *always* in the

PYRITE
St. Gothard's, Switz.
Bement Collection, American Museum of Natural History

PYRITE
Central City, Col.
Bement Collection, American Museum of Natural History

same plane. It suggests the tetragonal system and offers resemblances in its forms to that system. As in the tetragonal system the normal or type number of faces in the prism and pyramid can be doubled, and thus dihexagonal forms produced, while the withdrawal of half the faces in these expanded forms effects the important hemihedral forms of the *scalenohedron,* and *trapezohedron.* Among minerals crystallizing in this system the larger number assume hemihedral forms.

It is quite evident that we can form upon the axes thus related, viz, one principal vertical axis, and three in one plane at right angles to it, prisms and pyramids, the prisms being regarded as *open* forms of the pyramids, or forms wherein the faces of the latter intersect the vertical axis at an infinite distance. It is also clear that we can have the horizontal axes intersecting the horizontal edges of the pyramid, at the angles of the faces, or at the center of the faces (Figs. 154, 155). This divergence of intersec-
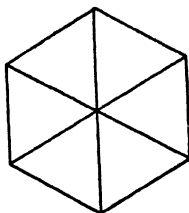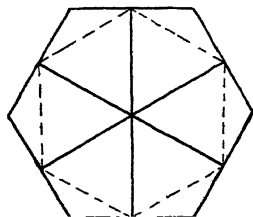
Fig. 154   Fig. 155

tion forms pyramids of the first, *proto,* (Fig. 154) or second, *deutero* order, (Fig. 155). Similarly it is clear that in the prism. the horizontal axes may intersect the edges between the faces, or in the center of the faces, and here again prisms of the first *proto.* or second, *deutero,* order are formed. As already mentioned, in the hexagonal system we find twelve sided pyramids (Fig. 151) and twelve sided prisms, and here it will be observed we have a hypothetical doubling of the axes, to support, as it were, the angles between the *original* axes, which angles are only alternately equal.

The basal pinacoid, as in all systems, is the limiting plane of the vertical axis.

Formulae of Hexagonal Crystals.

Considerations previously adduced in other systems makes O P, the sign of the basal pinacoid; *m* P, the sign of the proto pyramid in which any face of the pyramid intercepts two lateral

axes at equal distances from the vertical axis, and the axes are themselves respectively parallel to two faces on opposite sides of the vertical axis; m P2 the sign of the deuteropyramid, in which a face intercepts one lateral axis at a unit distance from the vertical axis (the case of the lateral axis bisecting it) and intercepts either one of the other two lateral axes at twice that distance (let the pupil prove this by redrawing Fig. 155); ∞ P is the sign of a face of the proto prism, which face is parallel to the vertical axis, or meets it at an infinite distance, and cuts the lateral axes which it intersects, at equal distances from the vertical axis; ∞ P 2 is the sign of a face of the deutero prism arising similarly from the relation shown in the face of a deutero pyramid; m P n is the sign of the face of a dihexagonal pyramid wherein each face intersects two neighboring lateral axes at unequal distances from the vertical axis; similarly ∞ P n is the sign of the face of the dihexagonal prism; but n never exceeds the value 2.

It is evident, throughout this symbolism of Naumann's that three axes alone are considered, though a rigid respect for the hexagonal construction would involve four elements in the symbol, each one determining the relation of a face to each of the four axes. And this amplification obtains in the systems of Weiss and Miller. Naumann attains his greater simplicity, in that he considers only two of the horizontal parameters (intercepts) and the third, which is self-explained, is disregarded.

Forms in the orthorhombic system, where there is a combination of prism and pinacoids, closely resemble hexagonal crystals, and this is illustrated in nature in the minerals Carnallite, Aphthitalite, and Cordierite, (Iolite). (Ask pupil to demonstrate this).

COMBINATIONS OF HOLAHEDRAL
HEXAGONAL FORMS.

Plate 8 illustrates the combination of hexagonal forms in single crystals.

EXPLANATION OF PLATE 8.

Fig. 156, Hexagonal prism and pyramid; Fig. 157, Hexagonal pyramid; Fig. 158, Basal pinacoid, hexagonal pyramid, hexagonal prism, dihexagonal prism; Fig. 159, Basal pinacoid, two hexagonal pyramids, hexagonal prism; Fig. 160, Basal pinacoid, hexagonal
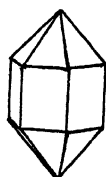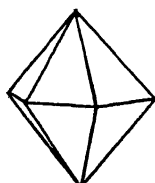
Fig. 156   Fig. 157   Fig. 158   Fig. 159
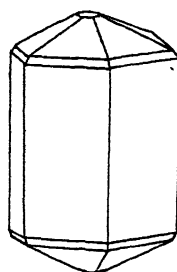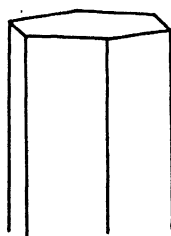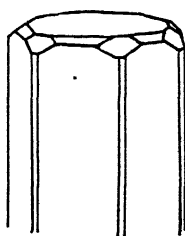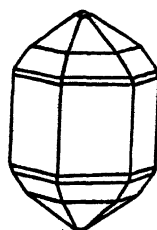
Fig. 160   Fig. 161   Fig. 162   Fig. 163
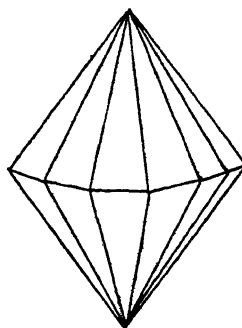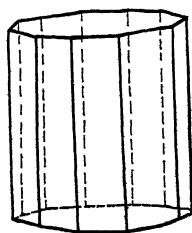
Fig. 164   Fig. 165   Fig. 166

PLATE 8
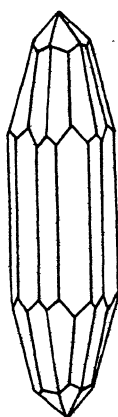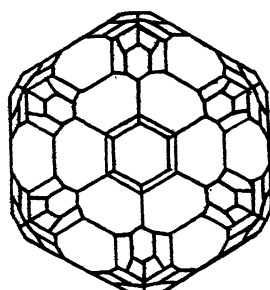
prism; Fig. 161, Basal pinacoid, two pyramids, (proto and deutero), two prisms (proto and deutero); Fig. 162, Three hexagonal pyramids, hexagonal prism; Fig. 163, Dihexagonal pyramid; Fig. 164, Dihexagonal prism; Fig. 165, Hexagonal pyramid, dihexagonal pyramid, two hexagonal prisms; Fig. 166, Summit of crystal, series of successive dihexagonal and hexagonal pyramids. (Note: the pupil should take Plate 8, and without mentioning the forms repeat the symbols for each. The teacher should, in this system, illustrate briefly the use of formulæ with four symbols, for which purpose, the following paragraphs will prove helpful; Weiss indicated in the hexagonal system the half of the vertical axis of the ground form by c, the three equal half lateral axes by a. Every face of the ground form (protopyramid) cuts the vertical axis, two of the lateral axes, at equal distances from the former, and is parallel to the third; its symbol is consequently, a, a, ∞ a, c. The protoprism with its vertical faces is derived, or results, from the protopyramid, through the infinite extension of the vertical axis, and its symbol becomes a, a, ∞ a, ∞ c. The basal pinacoid, parallel to the plane of the lateral axes, has the symbol: ∞ a, ∞ a, ∞ a, c.

The faces of the deuteropyramid cut all the three lateral axes, as well as the vertical axis, and of the former, one, at half the distance from the vertical axis, as the other two, whereby its formula becomes a, $\dfrac{a}{2}$, a, c, or (reduced) $2\,a$, a, $2\,a$, c. From this the formula of the deuteroprism is easily determined as a, $\dfrac{a}{2}$, a, ∞ c; or $2\,a$, a, $2\,a$, $\infty\,c$, as it is a deutero pyramid with vertical faces.

The faces of the dihexagonal pyramid cut the vertical axis, and the three lateral axes, but they intersect each of the latter at different distances from the former, with one parameter (intercept) always the smallest. If this smallest is made a, the largest sa, then from the necessary relations, the third becomes $\dfrac{s}{s-1}$ a. Is the largest parameter $3\,a$, then the third becomes $\dfrac{3}{2}$ a, is it $4\,a$, then the third is $\dfrac{4}{3}$ a. Thus the typical formula becomes sa, a, $\dfrac{s}{s-1}$ a, c; for which we can also write a, $\dfrac{1}{s}$ a, $\dfrac{1}{s-1}$ a, c. The symbol of the dihexagonal prism is the same as that of the dihexagonal pyramid only with ∞ c substituted, or sa, a, $\dfrac{s}{s-1}$ a, ∞ c.

MARCASITE
Felsobanya, Hungary
Bement Collection, American Museum of Natural History

PROUSTITE
Charñacillo, Chili
Bement Collection, American Museum of Natural History

HEXAGONAL HEMIHEDRISM.

In the process of halving the whole forms of the Hexagonal System, a number of interesting forms are developed, and these assume much importance in nature. These again can be halved and tetartohedral forms result. We have mentioned two, and quite predominant hemihedral forms, the rhombohedron, and the scalenohedron; with them the trapezohedron, trigonal prism, ditrigonal prism, tritopyramid and ditrigonal pyramid, trigonal pyramid, are to be placed, while as tetartohedral forms there are trigonal trapezohedron, the skew trigonohedron (a sort of trigonal pyramid) and a skew rhombohedron which is geometrically a rhombohedron.

To produce the hemihedral forms, half of the faces of the whole forms are removed, and the remaining faces extended until a *closed* form results; and the method or order of removal will change the result.

A *rhombohedron,* as already stated, is formed, as is illustrated in Fig. 167 by the removal of the alternate faces of the hexagonal
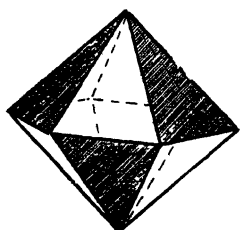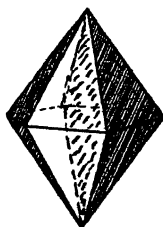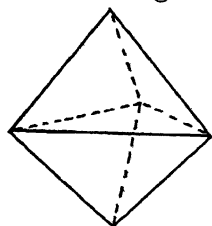
Fig. 167   Fig. 168   Fig. 169

pyramid above and below the median line; if the faces are removed in alternate *pairs above and below the median line,* Figs. 168-169 show the result, in a *trigonal pyramid.*

A *scalenohedron* is derived from a dihexagonal pyramid, by the removal of the faces above and below the median line in alternate pairs; Figs. 170-171; if the faces of the bihexagonal pyramid are
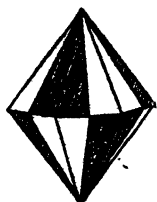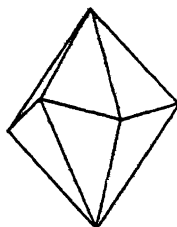
Fig. 170   Fig. 171

removed singly and alternately above and below the median line
a *trapezohedron* is formed—Figs. 172-173; if the faces in alternate
pairs, above and below the median line of a bihexagonal pyramid
are removed the remaining faces form a regular hexagonal pyra-
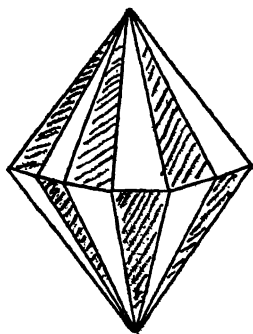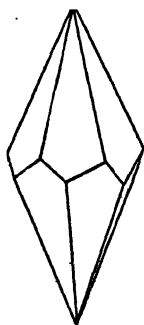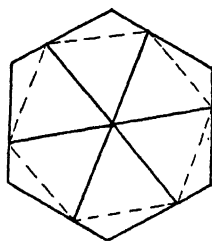
Fig. 172   Fig. 173   Fig. 174

mid, but one of the third order, or a *tritopyramid* is produced, in
which the lateral axes cut the horizontal edges dysymmetrically
(Fig. 174).
     The *ditrigonal proto-pyramid* is formed from a dihexagonal
pyramid by suppressing faces in alternate pairs in either hemisphere,
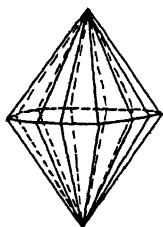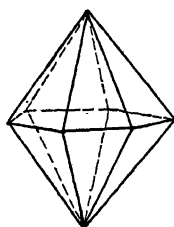
Fig. 175   Fig. 176

and in adjacent pairs on opposite sides of the equatorial plane;
Figs. 175-176.
     The *trigonal* prism results from the removal of alternate faces
of the hexagonal prism; Figs. 177-178; the *tritoprism* from the
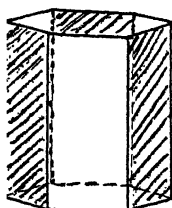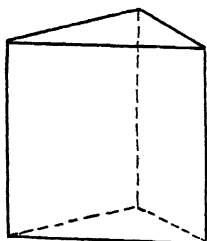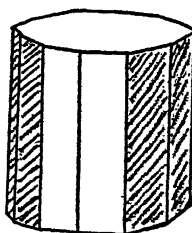
Fig. 177   Fig. 178   Fig. 179   Fig. 180
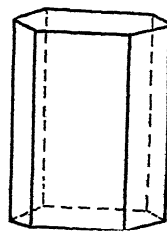
suppression of alternate pairs of faces in the dihexagonal prism; Figs. 179-180.

The *trigonal trapezohedron* is a tetartohedral form, being the
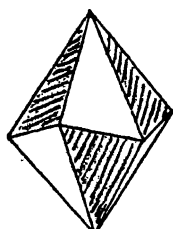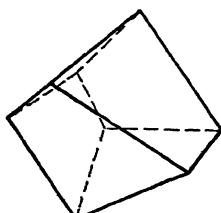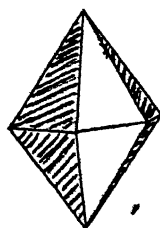
Fig. 181   Fig. 182   Fig. 183
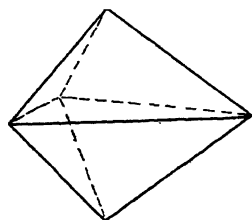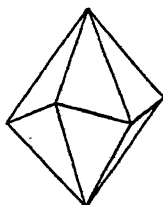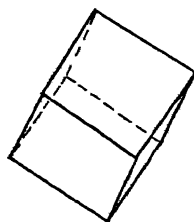
Fig. 184   Fig. 185   Fig. 186

divided *hexagonal scalenohedron;* Figs. 181-182; (*quartz*).

The *skew trigonohedron* is a tetartohedral form, being the halved *tritopyramid;* Figs. 183, 184.

The *skew rhombohedron* is a tetartohedral form, being a halved hexagonal scalenohedron; Figs. 185-186, the faces above and below the equator being differently eliminated from the case of the trigonal trapezohedron; which see.

All of the forms above enumerated are not found in nature. The symbols of the hemihedral forms are not always simply
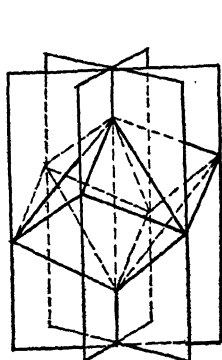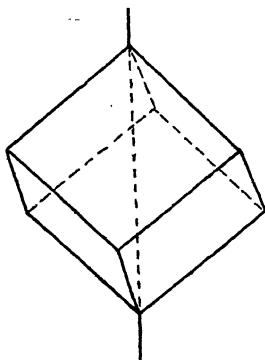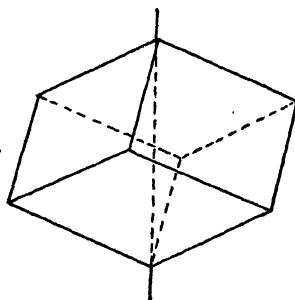
Fig. 187   Fig. 188   Fig. 189

the symbols of the holohedral forms divided by 2, as, for the rhom-- bohedron $\frac{mP}{2}$ As, from many considerations it is desirable to give to the rhombohedron an especial symbol and to designate the rhombohedron, deduced from the primitive pyramid P by R, the rhombohedron derived from $m\,P$ becomes $m\,R$, and is positive ($+\,m\,R$) or negative ($-\,m\,R$) as the front *edge* of the rhombohedron is in the first or second sectant of the six upper and lower sectants formed by the intersection of three planes at right angles to each other, Figs. 187, 188, 189. Fig. 187 shows the intersection of three planes and the six upper and lower sectants, Fig. 188 is a positive rhombohedron, Fig. 189 is a negative rhombohedron. The symbol of the scalenohedron is $m\,R\,n +$ or —, that of the trapezohedron $\frac{mPn}{2}$ right and left.

COMBINATIONS OF HOLO AND HEMIHEDRAL FORMS. PLATE 9.

Fig. 190, Hexagonal prism and rhombohedron; Fig. 191, Two rhombohedrons, right and left, positive and negative; Fig. 192,

PINK FLUORITE
Near Gaschenen, Switz.

PINK FLUORITE ON QUARTZ
Grimsel, Switz.
Bement Collection, American Museum of Natural History

rhombohedron and scalenohedron; Fig. 193, Two scalenohedrons;
Fig. 194, pyramid of the first order; Fig. 195, pyramid of the
second order; Fig. 196, Two rhombohedrons, trigonal prism and
hexagonal prism; Fig. 197, Two rhombohedrons, and pyramid of
the second order; Fig. 198, Basal pinacoid and rhombohedron;
Fig. 199, Rhombohedron, and two scalenohedrons; Fig. 200, Basal
pinacoid, rhombohedron, two hexagonal pyramids, hexagonal
prism; Fig. 201, Basal pinacoid, rhombohedron, hexagonal pyra-
mid, hexagonal prism; Fig. 202, Four rhombohedrons, two scalen-
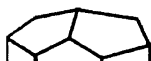
Fig. 190
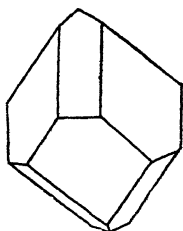
Fig. 191
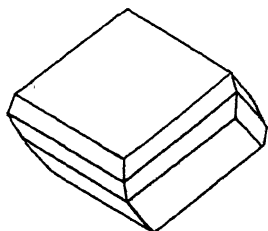
Fig. 192
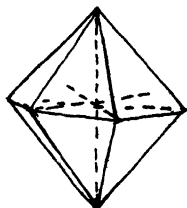
Fig. 194
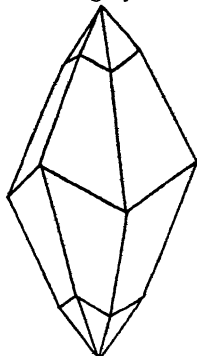
Fig. 193
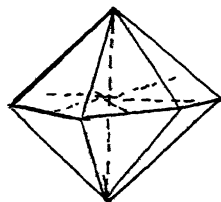
Fig. 195

Fig. 196
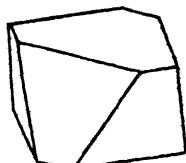
Fig. 198
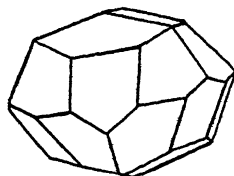
Fig. 197
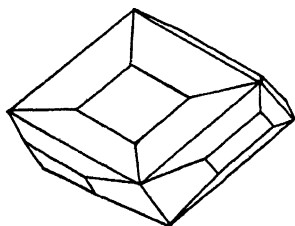
PLATE 9

Fig. 199
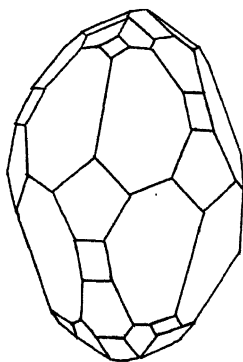
Fig. 200

Fig. 202
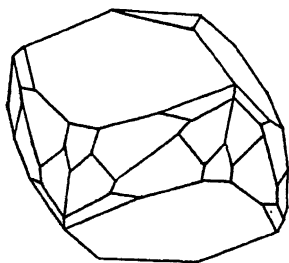
Fig. 203
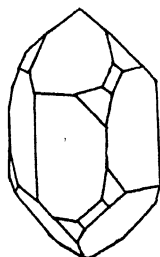
Fig. 204
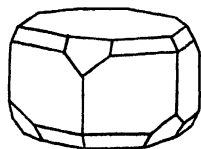
Fig. 201

PLATE 9 (Continued)

ohedrons and hexagonal prism; Fig. 203, Basal pinacoid, two rhombohedrons, three scalenohedrons; Fig. 204, (Quartz), Hexagonal prism, two rhombohedrons (forming terminal pyramid), and trapezohedrons, (the two four-sided faces at the angles above and below the prism). One face, a third order pyramid.

(Note: in this plate of the hexagonal forms, as in the other plates of the other systems, the figures are not lettered, and the pupil should point out the different forms as the name is read from the explanation of the plate. He or she should also draw, greatly enlarged (three or four times), the figures on the blackboard using the text-book, and the teacher should, from more extended works, draw other figures which the pupil must be required to analyze).

Hemimorphism.

The term *Hemimorphism* is used to designate the dissimilar termination of a crystal, i. e., when dissimilar or different planes are found at the opposite ends of a crystal, as in tourmaline, greenockite, calamine. Fig. 205 (tourmaline), upper end, two rhombohedrons, lower end, basal pinacoid; Fig. 206 (calamine), upper end, basal pinacoid, two macro and brachy domes, lower end brachy
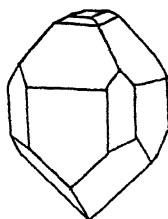
Fig. 205   Fig. 206

pyramid. This hemimorphism is associated with the development, upon friction, of opposite electricities (positive and negative) at the two differently faced extremities of the crystal.

In large museum collections there is placed for inspection a number of crystal models which partially explain the geometrical relations of the different systems and illustrate to some extent the manner in which one crystalline form is modified by another, for it must be carefully understood that in crystals in nature the planes or faces of different forms, *belonging however all to one system*, are associated, and we find upon one fundamental or predominant form the modifying traces, as truncating planes or facets, of many other forms. This occurs often in great elaboration, giving a very complex and highly intricate appearance to the summits of crystals.

TWINNING.

Natural crystals occur combined in groups, and by intersection, intergrowth and super-imposition form a variety of instructive and beautiful combinations. When they combine in certain symmetrical fashions, uniting along a plane which is a possible face of each crystal or about an edge or axis which may be a possible edge of two crystals, the union is designated as a "twin," and the process or form of union as "twinning." Twin crystals are quite usually

indicated by "re-entrant" angles, which form "notched, jagged, heart-shaped, knee-shaped, or arrow-headed" forms, and their union may embrace a number of separate crystals, as in "Alexandrite," Fig. 207, or in Staurolite, Fig. 208. Two crystals may so combine as a twin as to have the appearance of a single crystal. The union of the two crystals of hemimorphite (Fig. 209 from Miers) is obviously a twinning, but a little further interpenetration, and the re-entrant angles disappear, and Fig. 210 has the aspect of a single crystal.
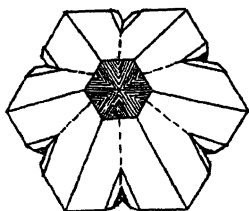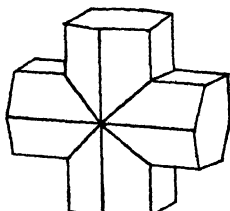
Fig. 207   Fig. 208   Fig. 209   Fig. 210

When crystals twin together in a repetitive series, first two, then a third, then a fourth and so on, the process is called *repeated* twinning. Such repetition may produce a closed (cyclical) angular ring (Fig. 211, rutile) or an extended crystal in a linear arrange-
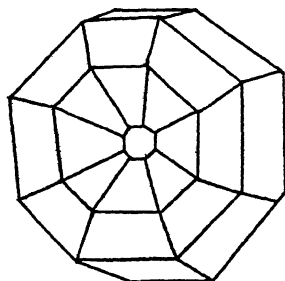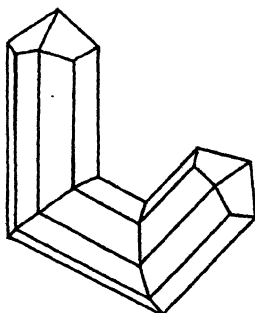
Fig. 211   Fig. 212   Fig. 212 A

QUARTZ CRYSTALS
Magnet Cove, Arkansas
Jesup Gift, American Museum of Natural History

ment of the twinning units (Fig. 212). Repetition appears significantly in twin lamellae, where the individual crystal reduced to a thin table is repeated indefinitely, and produces under a magnifying glass the effect of striae. Crystals of the triclinic feldspars are often thus built up (Figs. 213, 214), and the structure is known as polysythetic.

Fig. 213   Fig. 214

Plate 10 illustrates twinning crystals.
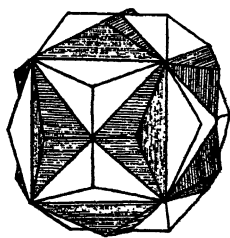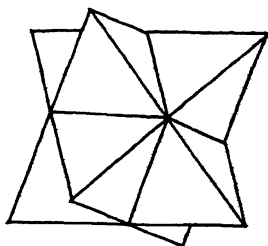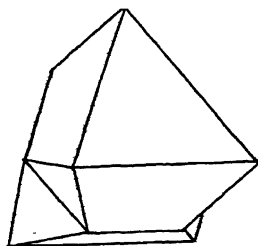
Fig. 215   Fig. 216   Fig. 217
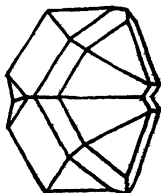
Fig. 218   Fig. 219   Fig. 220
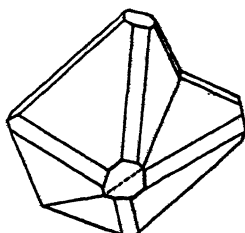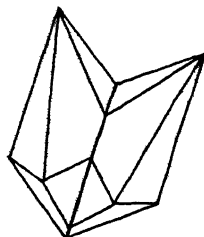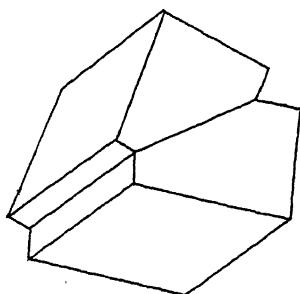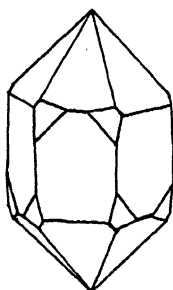
PLATE 10

Fig. 221　　　　Fig. 222　　　Fig. 223　　　Fig. 224
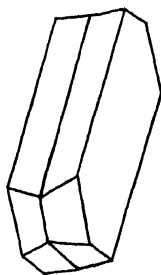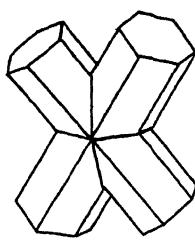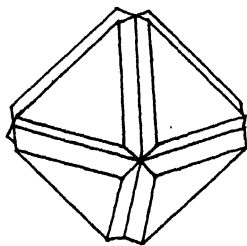
Fig. 225　　　　Fig. 226　　　　Fig. 227

PLATE 10 (Continued)

EXPLANATION OF PLATE 10.

Fig. 215, Interpenetration twin of two crystals (pyritohedrons) of pyrite; Fig. 216, Interpenetration twin of two tetrahedrons; Fig. 217, Twin crystal of Spinel, two octahedrons; Fig. 218, Twin crystal of Cassiterite, inclined prisms; Fig. 219, Twin crystal of Cassiterite; Fig. 220, Twin of Calcite, two scalenohedrons; Fig. 221, Twin of Calcite, two rhombohedrons; Fig. 222, Interpenetration of two (right and left) quartz crystals appearing as a single crystal (See quartz); Fig. 223, Twin of Gypsum; Fig. 224, Twin of Albite; Fig. 225, Twin of Mica; Fig. 226, Twin of Staurolite; Fig. 227, Twin of Haüynite.

Twinning was very early observed in the minerals *cassiterite* and *spinel*, and Romé de l'Isle was the first to draw attention to a possible explanation of the composite form, though he offered no idea as to why the twinning occurred, nor any explanation of its growth. In large collections the exhibition of twinned crystals (one of the most interesting and remarkable features in crystallography) may be considerable. Developments of twins are well

shown in the following species: Spinel, Diamond, Sphalerite, Copper, Fluorite, Pyrite, Cassiterite, Rutile, Chrysoberyl, Zircon, Aragonite, Cerussite, Mispickel, Chalcocite (*redruthite*) Staurolite, Calcite, Quartz, Gypsum, Orthoclase, Harmotome, Albite.

(Note: The teacher must exert his ingenuity in explaining to the pupils the theory and process of twinning. He should analyze the examples given in Plate 10, and draw others, and especially will he find it useful to employ the wooden models of twin crystals, furnished by the Ward Natural History Establishment of Rochester, to demonstrate the twinning functions of crystals).

SYMMETRY.

This word represents a relation of parts in crystals of great importance to the crystallographer. It may best be understood by reference to the planes of symmetry which any typical crystal in any of the systems contains. A plane of symmetry is a plane cutting a crystal in such a way as that the divided halves of the crystal are identical, though, of course, as right and left sides. Take an hexagonal prism, stand it on a mirror; the plane of the mirror is a plane of symmetry with reference to the prism and its reflection. Bisect the prism by a horizontal plane and it becomes a plane of symmetry to the divided halves, as these resemble each other in detail throughout their angles and faces. Now it is obvious that in this same hexagonal prism three vertical planes can be imagined, cutting, or bisecting it in a vertical sense, all of which it is readily seen are planes of symmetry, viz, the faces and lines of the crystal on either side of the plane are similarly related to this plane; the edges and angles of the same size, the faces of the same position. The grade of symmetry varies in the different systems of crystals, according to the number of planes of symmetry permitted in each.

In the Triclinic System there is no plane of Symmetry.

In the Monoclinic System there is one plane of Symmetry.

In the Orthorhombic System there are three planes of Symmetry.

In the Tetragonal System there are five planes of Symmetry.

In the Hexagonal System there are seven planes of Symmetry.

In the Isometric System there are nine planes of Symmetry.

The fundamental law which underlies crystallography is the *law of symmetry*. It may be formulated thus: every face of a crystal must possess a corresponding face parallel to it on the opposite side of the center of symmetry, and there must also be faces corresponding to these on the opposite sides of the planes of sym-

metry, and making equal angles with them respectively. A group of faces which are mutually related in accordance with this law is technically described as a *form*.

(Note: The teacher should take models of crystals in all the systems, and demonstrate the *fact* of these planes of symmetry. A simple plan is to form a large crystal in modeling wax and cut it with planes of cardboard or sheet tin. For example, model for the triclinic a crystal of *Albite;* for the monoclinic, a crystal of *Gypsum* or *Orthoclase;* for the orthorhombic, a crystal of *Sulphur;* for the tetragonal a crystal of *Vesuvianite;* for the hexagonal, a crystal of *Beryl;* for the isometric, a crystal of *Galena*).

Symmetry in recent and advanced works on crystallography has been made an almost exclusive principle in the classification of crystals, to the partial elimination of the old systems, and the *abolition of the old idea of hemihedrism,* as explaining derivative forms from halved holohedral forms. Symmetry of course has a deep philosophic value in crystallography but, fully expanded, it becomes confusing. Some of the classes of symmetry have not been yet discovered in nature, and, only recently, as pointed out by Rogers, the new mineral Benitoite exemplifies a class of symmetry hitherto unrecognized in nature. The reader should consult the excellent text-book of Moses and Parson entitled "Mineralogy, Crystallography and Blow-pipe Analysis," for an exposition of its meaning and application. It is unnecessary to illustrate the classes here but one may be referred to. The thirty-second class is called by Moses the Hexoctahedral Class; its scheme of planes of symmetry is shown in a cube bisected by *nine* planes forming on each face of the cube eight triangular spaces, which multiplied by the number of faces of the cube (6) give 48 spaces. These are shown in a crystal form in a *hexoctahedron* (Fig. 31) of which the *limit* form is obviously the cube. There are other limit forms as the rhombicdodecahedron, tetrahexahedron, octahedron, trigonal trisoctahedron, and tetragonal trisoctahedron, or, all the holohedral forms of the *isometric* system. It makes an excellent practice for the teacher to take Prof. Moses' book, and, throughout the classes of symmetry given by him, show how the *limit forms* arise from the general form in each class of symmetry. This can be done in the isometric forms with a more or less flexible model which can be compressed or elongated, and which initially, for the 32d class, shows the hexoctahedron with its six faces in each octant.

In the hexagonal system, the twenty-seventh class of symmetry is illustrated in the general form of the Dihexagonal Pyramid which, dissected by six vertical planes, and one horizontal plane, gives twenty-four faces; of which again the *limit forms* are
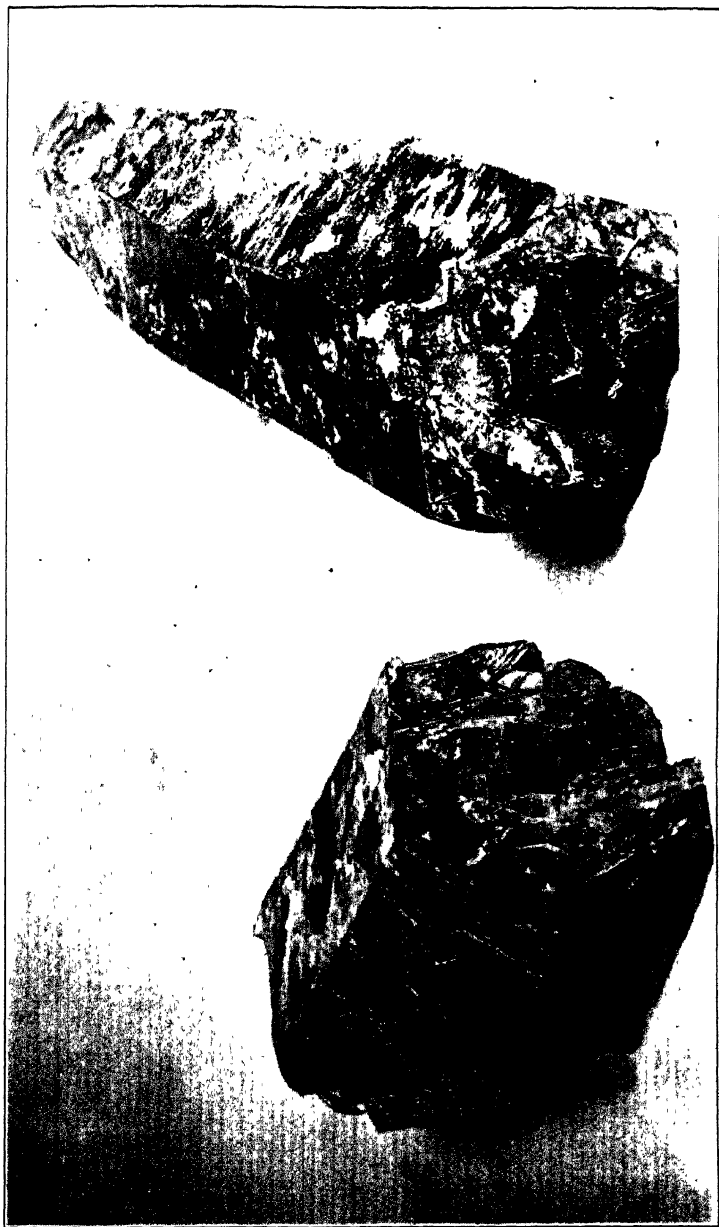
QUARTZ (halves of broken crystal; recrystallized surfaces)
Crystal Peak, Col.
Bement Collection, American Museum of Natural History

the basal pinacoid, hexagonal prism of the first order, hexagonal prism of the second order, dihexagonal prism, hexagonal pyramid of the first order, hexagonal pyramid of the second order, or all the holohedral forms of the *hexagonal* system.

It has been felt that the reference of crystal forms to classes of symmetry is preferable to their reference strictly to rigid systems which are now more regarded as artificial conveniences. It has been said (Lewis) that "the idea of menohedrism (hemihedrism, etc.), leads to inconsistencies, and to representations of the crystals which are not in accordance with the facts."

In this popular and *general* presentation of mineralogical data the Naumann nomenclature, formulas, and conceptions (hemihedrism, tetartohedrism, etc.), have been adopted as easier of apprehension, practically valid, and most concise. The Miller notation has now together with the Weiss symbols largely surplanted it, but for purposes of discussion by anyone not intending to pursue the subject into extreme scientific detail the Naumann method has advantages of simplicity. Of course to quote Prof. Moses "to represent a crystal form a symbol must be equally satisfactory for all faces of the form, and be quite independent of the absolute position of these faces so that it may be applicable to crystals of all sizes, and to the most unequally developed forms."

HEMIMORPHISM.

Many minerals (*Tourmaline, Struvite, Greenockite, Calamine*) crystallize with the opposite terminations of the crystal quite contrasted in the faces displayed. This difference is called *hemimorphism*. It is governed by law, and is associated with a difference in physical characters, as different electrical conditions under heating. It has no relation to *hemihedrism*. Figs. 228 (= Fig. 205), 229 show the hemimorphism of a tourmaline crystal (one end with two rhombohedrons, the other with basal plane) and of a

Fig. 229
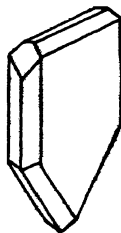
Fig. 230

calamine crystal (one end, base and brachy dome, the other brachy pyramid). Frequently an irregular development of faces at opposite ends of a crystal takes place, as in topaz, calcite, wiluite, etc., but this is quite another matter and has no reference to true hemimorphism. Hemimorphite (*Calamine*) (deriving its name from this feature) shown in Fig. 230, is a combination of the macropinacoid, prism, and at the uppermost end basal plane, macrodomes, brachy domes, and at the nether end the pyramid.

DISTORTION OF CRYSTALS.

As crystal models are prepared, the symmetry of the forms studied, in a physical sense, is perfect, but a very slight inspection of any collection of minerals reveals a very constant apparent dyssymmetry; unequal faces, long and short similar edges, inclined positions, and sometimes elongations, flattenings and oblique distortions, which quite alter the regular form, if ideally drawn. Fig. 231 shows a spinel elongated so that the nucleal octahedron, whose faces are produced, become disguised in the inclined rhomboidal prism with truncated angles. Similarly Fig. 232 shows the distortion of a rhombic dodecahedron of garnet and Fig. 233 the octahedron (flattened into one plane), a remarkable result often seen in a flat sheet of gold of a series of parallel octahedrons. In all such cases the angles made by adjoining faces in a crystal of a mineral are the same as those determined in the unchanged and
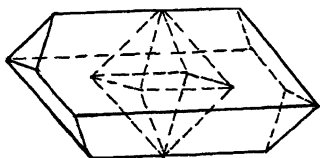
Fig. 231
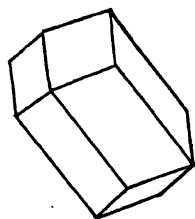
Fig. 232
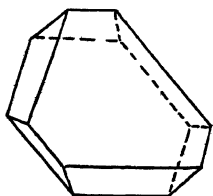
Fig. 233

Fig. 234
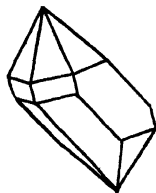
Fig. 235

ideal form, as in Figs. 234, 235, of quartz, the angles of the first are still maintained in the inclined distortion, and such angles are the same in any crystal of the mineral wherever found, and to whatever extent distorted by pressure. That is, there is crystallographic identity. Such distortions are quite generally due to the preponderant growth of the crystal along certain faces or in certain directions.

Throughout crystalline forms in minerals there is unvarying uniformity. A mineral may have a great many crystal combinations—in calcite there are nearly 900—but all are referable to one system, and their geometrical principle is absolutely identical.

Crystals of minerals in nature occur curved, intersecting, interfering with each other's growth, hollow, tubular, eroded (i. e.. dissolved-away by some mineral solvent as hot alkaline waters), pitted, their faces delicately etched, (this etching is very significant; it is related to the crystallographic system or the crystal's symmetry, it may appear as depressions or pits, or little elevations; *magnetite* when etched artificially with acids shows square elevations on the cubes, rectangular holes on the rhombic dodecahedron, and triangular pits on the octahedral faces; diamonds often display beautiful natural etching; in nature carbonic acid and hot water under pressure are etching agents), striated from oscillation of different face developments, as the ruled lines on the prism face of quartz, which record the intermittent tendency of the crystal to complete itself with a pyramid. Crystals of the same mineral in the same specimen show differences in size, they are also developed in contrasted phases, sometimes appearing stout, well defined, individualized and then as encrusting films on rocks or in arborescent shapes, as plumose aggregates, in spheres, botryoidal and in other mimetic forms explained in the succeeding section on Descriptive Terms.

Fig. 236

Fig. 237

PLATE 11
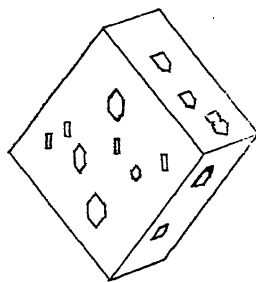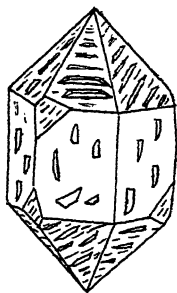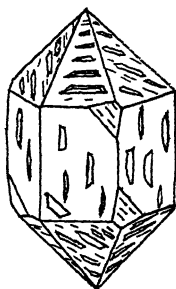
Fig. 238

Fig. 239

Fig. 240

Fig. 241

Fig. 242

Fig. 243

Fig. 244

PLATE 11 (Continued)

SMOKY QUARTZ
Maderanerthal, Switz.
Bement Collection, American Museum of Natural History
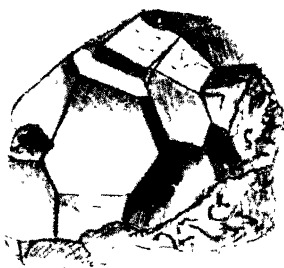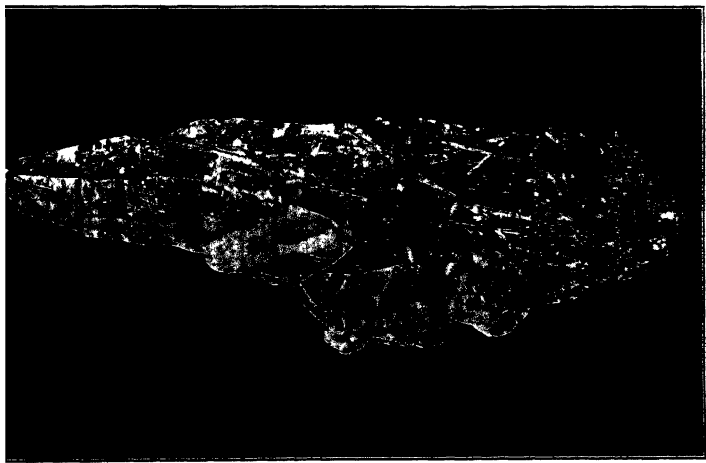
QUARTZ (containing tremolite)
Tavetsch, Switz.
Bement Collection, American Museum of Natural History
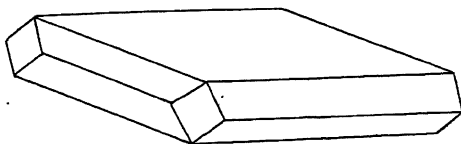
Fig. 245   Fig. 246

PLATE 11 (Continued)

EXPLANATION OF PLATE 11.

Fig. 236, Curved Gypsum crystals; Fig. 237, Pitted Barite crystal (after etching); Figs. 238, 239, Etched Quartz crystals (left and right); Fig. 240, Cellular Apatite; Fig. 241, Interfering groups of Garnets; Fig. 242, Tubular Pyromorphite; Fig. 243, Broken Quartz (recrystallized on walls of fracture); Fig. 244, Eroded Pyroxene; Figs. 245, 246, Flat (*tabular*) and prismatic (*columnar*) Barite.

DESCRIPTIVE TERMS.

In the development of minerals their forms assume a variety of abnormal phases, or phases resulting from imperfect or interfering crystallization or peculiarities of physical conditions, and while remaining the same in chemical composition, specific gravity, crystallo-physical properties, these present to the eye "irregular varieties of aspect." In very old authors these inessential properties were made a great deal of, and different names were given to different phases of the same mineral so that the same mineral species became broken up under several designations, because of form, luster, color, occurrence, etc., an obviously artificial arrangement, and to which nothing could contribute order or stability or scientific exactness, but chemical analysis. Terms expressive of

the varying appearances in minerals have long been in use and immensely help description.

Acicular, needlelike, long, thin crystals; examples natrolite.

Amorphous, without crystallographic character, in massive aggregates; examples, opal, glass, fused arsenic, chalcedony.

Amygdaloidal, almond-shaped minerals filling ellipsoidal cavities in volcanic rocks are thus designated; examples, mesolite, thomsonite.

Botryoidal, bunchlike, referring to grapelike clusters of rounded hemispherical surfaces; examples, hematite, stream-tin, malachite.

Capillary, thinlike threads; examples, millerite, chalcotrichite.

Coralloidal, resembling coral in twisted, cylindrical growth; example, flos-ferri (aragonite).

Columnar, columnlike, in vertical or elongated partitions and polyhedrons.

Compact, close, solid, without apparent crystallization.

Curved, rounded; often applied to crystal faces that have elevated and curved contour, frequently produced by a succession.

Curvilaminar, made up of curved layers.

Dendritic, treelike, the mineral particles arranged in frondose shape, fernlike or aborescent; example, manganese dendrites, frost on glass, pavements, etc.

Drusy, applied to surfaces of minute crystals; example, drusy quartz, calcite, pyrite.

Earthy, without crystalline coherence pulverulent, ocherous.

Fibrous, in fibres, example, asbestos.

Filiform, in threads or wires as Wire-silver.

Geodic, in geodes, or more or less spherical cavities lined with crystals.

Globular, rotund, spherical, applied to concretions as in limonite balls, or to radiating spheres made up of divergent from-a-center crystals, as in pectolite.

Granular, made up of grains.

Leafy, in flat sheets or leaves; examples, leaf-gold, silver, copper.

Lenticular, in lenticles or leaves, thickening at the center, tapering or declining at the extremities; example, some gypsum.

Mammillary, resembling the nipples of the breast; limonite.

Micaceous, foliated in sheets.

Mossy, mosslike, made up of silklike threads aggregated in knots, bunches, wisps and sprays; example, byssolite (amphibole), chlorite, moss-agate.

Nodular, in nodules, kernels, lumps.

Pisolitic in pea-shaped concretions; example, aragonite from Carlsbad showing an agglomeration of closely packed spheres made up of successive crusts.

Powdery, when loosely coherent as dust, sand, ashes.

Prismatic, in prisms, long crystals as cyanite, tourmaline.

Pyramidal, in pyramids, used for minerals distinguished by a pyramidal habit, i. e., faces meeting at the opposite ends of a crystal, in pyramids.

Radiating, applied to crystallizations diverging from a center, a very frequent aspect in minerals; examples, pectolite, tourmaline, stilbite.

Reticulating, latticelike, made up of crossed intersecting bars, as some crystallized cerussite. (N. South Wales), rutile.

Reniform, kidney-shaped, as the opal, *menilite,* near Paris.

Rosette-formed, encircling and successional arrangement of crystals in rosettes; example, hematite (*eisenrosen*).

Specular, shining like a mirror—applied to glistening hematite.

Stalactitic, in stalactitelike shapes, descending mineral icicles.

Striated, streaked, crossed by lines, like rulings; example, quartz.

Tabular, flat, tablelike, as broad crystals, opposed to prismatic and columnar.

Terminated, when a crystal, as a prism, is completed, at one or both ends with crystallographic faces (pyramids, domes, pinacoids).

Warty, pustulose, e. g., roughened with pimples, stubs or grains.

Crystals of different minerals are in nature found associated with a sort of crystallographic sympathy, that is, the crystals of each are arranged, or disposed, with symmetry to each other. Thus octahedrons of magnetite cover faces of amphibole crystals, so that the faces of the former are parallel to the basal pinacoid of the latter, orthoclase (monoclinic) and albite (triclinic) grow together in parallel position, rutile (tetragonal) implanted on hematite (hexagonal) with its edges parallel to the edges of the hematite, cyanite (triclinic) and staurolite (orthorhombic) are thus related to each other in many occurrences, pyroxene and amphibole (both monoclinic), tetrahedrite and chalcopyrite, marcasite and pyrite, galena and sphalerite, calcite and quartz.

Rapid crystallization will often produce flat, angular surfaces of crystal groups, where, at prominent angles or edges of the first

formed crystals there has been a concentration of the solution or fusion from which the crystal arises, and star-shaped, tree-shaped, lattice, feather-like structures result (as in frost on a window pane).

Crystals also in their development enclose foreign material, as with garnet, tourmaline. quartz, beryl, amphibole, pyroxene, orthoclase, and are disturbed or impeded (especially if their growth is slow) in their completion. In such ways, as proven by Dauber, slight anomalies in the crystals occur, so that in the same group of crystals from the same locality aberrations take place, which are even more emphasized on comparison with the crystals of the same mineral from another locality. (Note: The teacher can well illustrate the more obvious discrepancies in crystals by selecting series of specimens of the same mineral from different localities, or varying associations, and instructively dwell upon contrasted size, bent, inclined, interfering crystals, *inclusions,* natural breaks, intervening obstructions and the peculiarities of surface and texture.) Crystals undergo fracture from earth movements, coalescence between their parts is interrupted by interposition of foreign material (as in tourmaline, garnet, pyroxene) and their surfaces vary from brilliant, glasslike planes, to dull, warped, hollow, convex, pitted, streaked, lined and finally very visible crystallographic elevations. Crystal faces have often been dissolved away (quartz, topaz) or etched, while so-called *vicinal* faces which are very obtusely inclined planes, barely lift themselves from the plane of the principal face (see Fluorite) and again subindividuals build up the crystal, and are separately recognized as its components, (galena, spinel, garnet, calcite) in the more or less delimited and projecting outlines of cubes, octahedrons, icositetrahedrons, scalenohedrons, etc. (Figs. 247, 248).
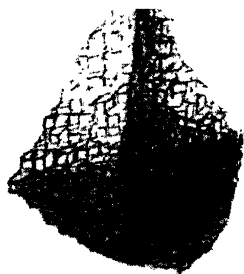
Fig. 247

Fig. 248

HYALITE
San Luis Potosi, Mexico
Bement Collection, American Museum of Natural History

QUARTZ (after Fluorite), ENCRUSTING
Lake City, Col.
Bement Collection, American Museum of Natural History

(Note: Under Descriptive Terms the teacher should dwell upon each subdivision, and illustrate the terms with as much material as he (or she) can assemble, introducing the results of observation and reading. The series of examples can be greatly (and profitably) extended.

GROWTH OF CRYSTALS.

Crystals grow at times freely in a liquid which has reached the proper degree of saturation as in the case of sugar crystallizing from a mass of syrup; or they are attached, and grow outward on the sides exposed to the incremental action of the surrounding fluid. The crystals of leucite in lava or pyrite in slate may be examples of automorphous or free growth. Perfect octahedra of alum can be made in a concentrated solution by suspending a small crystal already formed by a thread or even by thickening the solution with glue, though this latter by imposing some restraint upon the free movement of the molecules induces distortion and *twinning*. The slower the crystal is formed the more perfect it is. Some faces will grow more rapidly than others in isometric forms, and occasionally faces may be obliterated in forming alum crystals, while some change in circumstance hastens the replacement of angles and edges, by new faces; all such modifications being similarly developed over the nucleal crystal while in the disappearance of faces *like* ones vanish together. Solutions of common salt crystallizing at temperatures under 32° F. form hemi-trigonal trisoctahedrons (*deltoid dodecahedra*) or twinned tetrahedrons. Linck's observations are of interest; an important property of the individual units of a crystallized body, is their ability to *grow*. In many cases it can be assumed that the chemical *molecule* is the smallest possible crystal of the substance; in other cases the smallest crystal may be a simple multiple of the molecular weight, as determined by chemistry. If a crystal arises it first forms a germ; a germ (*Keim*) establishes a majority of similarly influenced molecules, and it is differentiated from the surrounding medium by an attracting force— the force of crystallization. If such a germ is present in a solution (itself in such a state of saturation, etc., as to induce the solidification of its units) it affects all its surrounding similar molecules as a magnet does neighboring magnetic needles, and this directive force decreases probably as the square of the distance. If the attraction overcomes the friction (tension) of the surrounding solution and its inertia then new molecules are set in motion towards the nucleus (*Keim*) and ever, as they approach it, with increasing

velocity. When it reaches the nucleus it enlarges it by parallel at tachment; the crystal grows.

As now different directions in the crystal are differently affected by the crystallizing force, so there arises directions of greatest and smallest *growth-velocity* (*Wachstumgeschwindigkeit*) whose relations to each other are certainly influenced by the chemical and physical properties of the surrounding medium. Thus it comes about that crystals of the same compound, under such variable circumstances, are bounded by variable faces. Directions of the greatest growth-velocity are indicated on the forming crystal by edges and angles.

In crystallization movements in the liquid are set up. There occurs what has been called "currents of concentration," passing successively over the face of a crystal, depositing thin coatings of substance, one after the other, (Paul Gaubert) until, for example, "one can see on a crystal of lead nitrate, having a diameter of half a millimeter as many as twelve of these successive layers deposited." M. Gaubert says: "these successive deposits have no interspaces and the crystal may be perfectly transparent. If the crystal of lead nitrate is, however, subjected to the influence of two or of several currents of concentration, the corresponding coatings laid upon it, start from different points in the periphery and may not be of the same thickness. Ordinarily they do not join exactly at their point of meeting. In this way are then produced inclusions and the crystal is no longer transparent but becomes milky. On a glass plate it is easy to produce at will a transparent or milky crystal of lead nitrate. In the experiment it is necessary to agitate the crystal very slightly with a needle in order to subject it to the influence of one or several currents."

Crystals formed rapidly have simple faces, and the complicated forms have grown more slowly. Foreign bodies (to the chemical nature of the crystallizing substance) curiously affect the crystal form, thus crystals of salt, ($Na\ Cl$), formed in urine, are regular octahedrons instead of cubes, the usual form. This is ascribed to the presence of urea and the reason, as explained by P. Curie, is that a capillary action, existing between the liquid and the crystal intervenes, and such faces develop as require, under different circumstances, *the minimum expenditure of capillary energy*. Gaubert has shown that the presence of foreign matter absorbed in the crystallizing of the colorless substance causes modification of form. There has been observed (Gaubert) an interesting inequality of absorption of the foreign matter dissolved by the different faces of the crystal. Thus methylene blue is not deposited on the octa-

hedral faces of the lead nitrate, but only on the faces of the cube and the pentagonal dodecahedron, and, yet more remarkably, if a colorless substance crystallizes in a solution containing two colors, each one giving characteristic forms, "the crystallizations thus obtained will be the two combined forms, so that one and the same crystal is composed of pyramids or of prisms of different colors" (Gaubert). It is easy to deduce from these observations some natural conclusions as to the varying influence, at successive intervals, of a varying solution in causing periodic and contrasted generations of crystals.

STRUCTURE.

Crystals in their development start with nucleal crystals which enlarge by accretion. The nucleal crystal may be quite different in form from the completed crystal as in barite (Fig. 249), calcite (Fig. 250), fluorite (Fig. 251), though in all such cases the nucleal
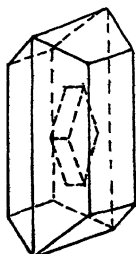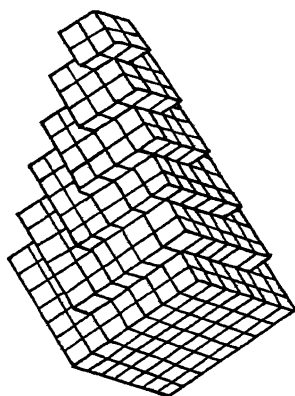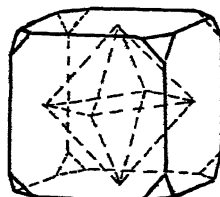
Fig. 249   Fig. 250   Fig. 251

and final form are referable to the same system. Quite usually the crystal enlarges undeviatingly, by regular additions, molecule by molecule, the final size being somewhat determined by the strength of the solution, or the frequency of the addition of fresh material in seeping or saturating currents. With the starting out of many crystals, interference, interpenetration, and blending in various ways occur. The crystal quite easily entraps in its growth impurities and foreign substances, which may be brought into crystallographic

relation to the enclosing crystal, being symmetrically disposed (Figs. 252, 253, 254) or may be very irregularly enclosed. These
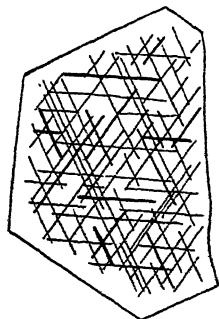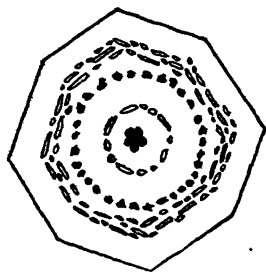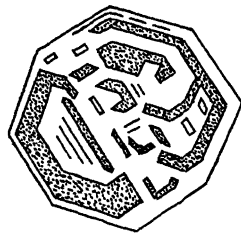
Fig. 252   Fig. 253   Fig. 254

appear as scales, needles, grains, or dust, or gas and water bubbles. Analyses of minerals are often marred by the unsuspected presence of foreign compounds and material for chemical investigation should be microscopically examined for the elimination of such substances. Such impurities often impart color to the containing mineral. Crystals of garnet, quartz, barite, tourmaline, fluorite, reveal in favorable examples the growth outward, from a center, of the crystal, by the superimposition, layer by layer or zone by zone of the crystallizing mineral. These are sometimes physically separated by films of foreign substances, by which the later crusts are feebly connected with the earlier, and become removable, as in Cap-Quartz, where mica constitutes the interposed body, and similar occurrences are observed in vesuvianite, garnet, epidote, wolframite.

Different minerals may be combined in the same crystalline growth as biotite (a mica), and muscovite; tourmaline layers of different colors and composition, also of garnet, while an octahedron of chrome-alum suspended in a colorless potash-alum becomes encased in a transparent envelope. The intergrowth of the feldspars is very well known, as in the alternating structure of orthoclase and albite. Porous, cellular or pitted conditions prevail in minerals through a loose aggregation or interrupted growth. The various descriptive terms previously reviewed indicate the very aberrant and greatly varied superficial aspects of minerals and represent modified states of consolidation from amorphous (colloidal or jelly-like; silica, opal), through *crystalline* (not crystallized) bodies, as agate, limonite, to the regularly bounded surfaces of crystals, quartz, beryl, diamond.

QUARTZ (after Barite) ENCRUSTING
Near Silverton, Col.
Bement Collection, American Museum of Natural History

QUARTZ (after Calcite)
Zacatecas, Mexico
Bement Collection, American Museum of Natural History

(Note: The teacher can enormously expand the foregoing paragraphs through examples, brought into the class-room, illustrative of the numerous possible physical configurations of minerals. Crystals should be broken, and their internal structure or texture, noted, amorphous masses opened and studied, while the concentric radiating lamellar scaly, granular construction of purely crystalline bodies should be examined).

PSEUDOMORPHISM.

By Pseudomorphism is meant the substitution of one mineral for another with the crystalline form of the second unchanged, Pseudomorphs arise in three different ways. (1) By encrustation, as when quartz coats calcite, concealing the covered mineral completely though assuming the crystalline form of the calcite. Such phases of pseudomorphism are called **Epimorphs.** (2) By the chemical alteration of a mineral, when, by losing a constituent or by gain of one, or by an exchange of one constituent for some other, the mineral has assumed a different chemical character, as the change of pyromorphite, the phosphate and chloride of lead, into galenite, the sulphide of lead; or the change of cuprite, the oxide of copper, into malachite, the carbonate of copper, where in both cases the crystalline form of the original mineral remains unmodified. (3) By replacement, when one mineral fills in the deserted cavities of a second mineral, or slowly displaces it in its crystalized condition, as when quartz fills the cubic spaces left by fluorite, or hematite takes the form of calcite. **Paramorphism is a** *molecular* without a *chemical* change, as when pyroxene assumes the form of amphibole. Those chemical salts or compounds are called *dimorphic* which appear in nature under two crystalline forms, as carbonate of lime, and *trimorphic,* when in three, as oxide of titanium, to which lately a fourth crystalline phase has been added. A very beautiful and remarkable example of pseudomorphism is exhibited among coppers by a number of interpenetrating crystals of pure copper, which have the form of azurite, the blue carbonate of copper, and from which they have been formed. The specimens are usually from Grant Co., New Mexico, and Mr. Yeates in commenting upon this peculiar substitution says: "The latter (azurite) must have lost its carbonic acid and water in the presence of some reducing agent, probably volcanic gases thrown up from below, leaving the copper in a spongy state, upon which the kaolin—always enclosing these pseudomorphs— was deposited, and forced by pressure, while in a soft, semi-liquid condition, into the pores of the sponge."

Pseudomorphism or the change of a mineral's composition proceeds gradually, and while the alteration may be generally from the exterior inwards, (frequently a superficial thickness is changed with the unaltered original mineral remaining within—pyrite, garnet), it can originate from the inside, and advancing towards the exterior leave a slender shell only of the first mineral unaffected. Air (oxygen), and water bring about these changes, and where elements are removed and are replaced by others, water solutions act naturally as effective carriers. The replacing mineral may closely follow the molecular arrangement of the replaced mineral (in this way the original cleavage is often retained) or it may be fibrous, micaceous, or granular. (Illustrations are given in pyrite, feldspar, olivine, siderite, etc.). Feldspars may alter from the interior, limonite may be changed to hematite (by loss of water) and yet retain its concentric and radiating fibrous structure, aragonite may fill the crystal outlines of gypsum and retain the latter's cleavage.

PHYSICAL PROPERTIES OF MINERALS.

The physical characters of crystals and minerals embrace their relations to Cohesion, Specific Gravity, Light, Heat, Electricity, Magnetism, Chemical Composition, and Blowpipe Characters.

Besides their chemical composition, whose discussion we have just hinted at, minerals possess certain physical attributes which are helpful, and indeed more commonly used for their determination. There are recognized in minerals seven kinds of **Lustre**.

1. *Metallic,* the luster of metals (copper).
2. *Adamantine,* the luster of the diamond.
3. *Vitreous,* the luster of glass (quartz).
4. *Resinous,* the luster of resin (sphalerite).
5. *Greasy,* the luster of oily surfaces (elaeolite).
6. *Pearly,* the luster of pearl (white mica).
7. *Silky,* the luster of silk (selenite).

There have been instituted for convenience ten degrees of **Hardness.**

1. Talc.	6. Feldspar.
2. Gypsum.	7. Quartz.
3. Calcite.	8. Topaz.
4. Fluorite.	9. Corundum (Ruby Sapphire).
5. Apatite.	10. Diamond.

There are planes of cleavage or direction in which minerals yield to pressure, in more or less smooth surfaces; these direc-

tions of course are along lines of least cohesion, and are usually parallel to the face or faces of some crystalline form. Thus there is cubic, octahedral, prismatic, and basal cleavage, which are often illustrated in introductory cases.

Besides these features minerals differ in specific gravity, in transparency, and in optical properties, in fusibility, magnetism, and electrical properties. As regards the specific gravity of minerals it is estimated upon the weight of an equal volume of water, and varies from a mineral as light as meerschaum (sepiolite), which may float, to the metal platinum, which is nineteen times heavier than water. The optical relations of minerals are various and often complicated.

In general, minerals are *isotropic, uniaxial* and *biaxial*. In isotropic minerals (properly those crystallizing in the isometric system) there is no double refraction; in uniaxial minerals (minerals crystallizing in the tetragonal and hexagonal systems) there is but one direction in which there is no double refraction, and in biaxial minerals (minerals crystallizing in the orthorhombic, monoclinic and triclinic systems) there are two directions in which there is no double refraction. These directions are known as the optic axes.

There is another peculiar property in minerals, an optical property, which is expressed in the term Pleochroism. This designates the phenomenon in minerals whereby seen in one direction (axis of absorption) one color appears, in another a second color, and in a third direction a third color is seen. These axes are apt to be three. Some minerals, as epidote, show this property with surprising beauty.

RELATION OF CRYSTALS TO LIGHT.

Reflection. When a ray of light strikes perpendicularly or at right angles upon any polished surface, as at *a, b,* (Pl. 12, Fig. 255), it is thrown back in exactly the same line; but if it falls obliquely it is reflected obliquely, as is shown by the arrows. The angle of rebound is equal to the angle of striking, or as it is commonly expressed, the angle of reflection is equal to the angle of incidence. Luster is an effect of reflection.

Refraction. When light passes from one medium to another of a different density, as from air to water, it is turned out of its straight direction. If its course be perpendicular to the surface, as at *ab* (Pl. 12, Fig. 256), it will not be diverted; but if it falls obliquely, as at *cd,* it will be *refracted* and proceed to *e*. If this refracting medium has parallel surfaces, the ray on leaving it is
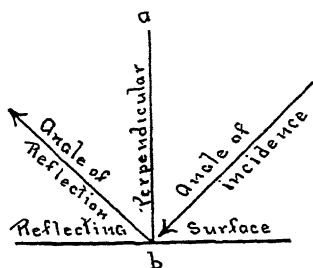
Fig. 255
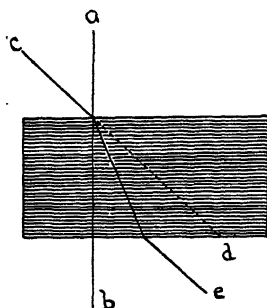
Fig. 256
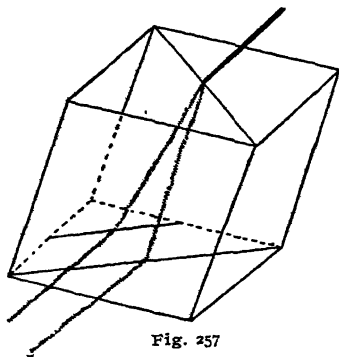
Fig. 257
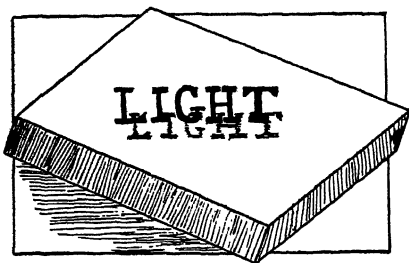
Fig. 258
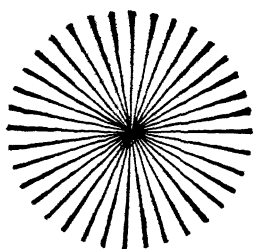
Fig. 259

Fig. 260

PLATE 12

again bent back, parallel to its original course, as is seen in the figure.

Double Refraction. Some substances possess the property of splitting the ray which passes through them, producing an effect

which is known as *double refraction* (Pl. 12, Fig. 257) as one ray outside of the substance becomes two rays (of less brilliancy) within it, and an object seen through such a doubly refracting medium may appear doubled (Pl. 12, Fig. 258). The wave theory of light affirms that in double refraction the ray of common light entering the doubly refracting substance is *separated* into two resulting rays, which are *polarized* in planes at right angles to each other. ·

Polarization. By the undulatory theory of light it is assumed that in common light the undulations take place in every plane that obtains or that the light may be represented as a round rod (Pl. 12, Fig. 259) the change in common light produced by polarization, causes the undulations to take place in *one* plane containing the ray, or the polarized light may be represented by a flat rod (Pl. 12, Fig. 260).

Now minerals crystallizing in the different systems, by reason of a differing molecular constitution, affect light in different ways; through minerals crystallizing in the *Isometric* system the light is simply refracted, that is, in whatever direction the ray of light falls on the isometric substances or crystals, it is simply bent, and passes through them as *one* ray; through minerals crystallizing in the remaining five systems there is *double* refraction, or an incident ray becomes separated, as explained above, into two rays.

Such crystals or minerals fall again into two groups, *Uniaxial* and *Biaxial,* according as there is *one* or *two* directions in which the incident ray undergoes *no double refraction.*

The *uniaxial* crystals belong to the tetragonal and hexagonal systems, the *biaxial* to the orthorhombic, monoclinic, and triclinic systems.

The lines or directions in these crystals, in which there is no double refraction, are known as the *Optic Axes.* In uniaxial crystals (tetragonal and hexagonal) the optic axis coincides with the principal crystallographic axes; in the monoclinic and triclinic they may or may not do so. These axes intersect so as to form an acute and obtuse angle, rarely a right angle. The plane containing them is the *plane of the optical axes.*

Besides the relations of light to crystals, expressed by *reflection, refraction, polarization,* there is another feature connected with the passage of light through crystal.

· In biaxial crystals there are three directions in which light is propagated at three different velocities—maximum, minimum, and mean—and these three directions are at right angles to each other. These directions are called the axes of elasticity.

Two of these, the axes of greatest and least velocity, lie in the plane of the optic axes, and they also bisect the angles made by the optic axes. When the axis of least elasticity bisects the acute angle made by the optic axes, the crystal is called *positive;* when the axis of greatest elasticity bisects this same angle, the crystal is called *negative.*

Finally these axes of elasticity vary with rays of different colored light, so that in such crystals there may not only be a different degree of refraction in the three different axes of elasticity, but these three different degrees may vary for different colored rays of light as well.

Supplementary details of elucidation of the foregoing generalized paragraphs follow.

When the observer begins his examination of the physical properties of minerals he at once sees that a crystallized body has a consistent and rigidly controlled texture, that its properties have fixed relations to direction and structure, that as Prof. Miers has written, "from the physical point of view a crystal is very different from the uncrystallized substance, just as a regiment is a very different thing from a crowd of men; the material may be the same, but it is differently arranged." The varying intensity or character of any of these physical properties may be graphically shown as conditioned by planes or axes of symmetry.
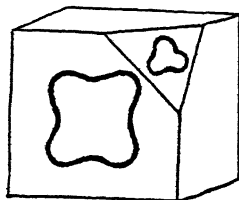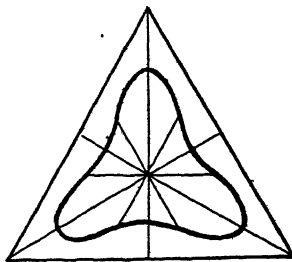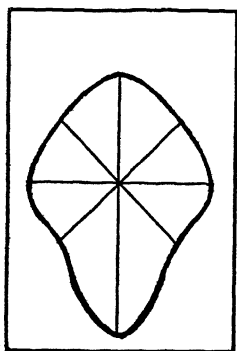
Fig. 261   Fig. 262   Fig. 263

Hardness; tests with a *sclerometer* (the teacher should describe this instrument and if possible improvise and use one in the class-room) show a changing hardness over the face of a crystal in different directions which when plotted give a symmetrical

QUARTZ CRYSTAL VASE
Morgan Gem Collection, American Museum of Natural History

geometrical figure (Figs. 261, 262, 263). Hardness is the resistance offered by a mineral body to separation under the pressure of a sharp point, and is usually tested on the face of a crystal. Hardness is curiously related to cleavage or the lines and planes of least coherence; faces of a crystal parallel to a cleavage plane are the softest, faces of a crystal at right angles to the cleavage face show two hardnesses, in lines parallel to the cleavage a less hardness than in lines perpendicular to that plane of separation; on a face inclined to the cleavage the same scratch line shows a varying hardness, viz, the greater hardness is shown when the scratching point moves from the obtuse angle of the intersection of the cleavage and the face, to the acute, and less in the opposite direction; there is no variation in the hardness of a face parallel to the cleavage. Hardness, as plotted in figures, is shown as a *circle, where* no differences of hardness in any direction can be detected as an ellipse or lobed figure when such exist. (Note: The teacher can profitably spend a whole instruction on testing the different hardnesses of minerals, pointing out the ascending resistance to pressure, from clay to quartz, and beyond, and explaining the danger of mistaking the abraded powder from the scratching point for removed dust from the scratched mineral).

Cleavage. The ultimate molecules of minerals are so disposed, that in the resultant crystals, planes arise along which the mineral will, the most easily, separate, and such planes have fixed relations to the crystalline form. By means of such cleavage directions on octahedral forms can be made from a cube of fluorite and a rhombohedron from a prism of calcite—or in other words, the cleavage of fluorite is in planes parallel to an octahedron and that of calcite to a rhombohedron. Such surfaces of least resistance are developed, and can be demonstrated, in the massive form of the mineral as well as in crystals. If such cleavage surfaces are so even and smooth as to make reflecting faces, as in mica and gypsum, the cleavage is called *perfect,* where the surface yielded is broken, irregular, uneven, the cleavage is called *imperfect.* The cleavage faces are usually parallel to primary faces of the crystal, as the basal pinacoid, (mica, topaz), the cube, (halite), the octahedron, (fluorite), the clinopinacoid, (gypsum), orthopinacoid, (borax), prism, (amphibole, spodumene, pyroxene), the rhombohedron (calcite), etc., etc. (Note: The teacher should thoroughly illustrate cleavage, bringing into the class-room specimens of minerals in all the systems, and subjecting them to cleavage, forming, where it is possible, *closed* forms, as an octahedron from fluorite. Also imperfect cleavage should be secured as in the *prismatic* cleavage of orthoclase). Besides cleavage, minerals possess *fracture,*

which is the manner of breaking of a mineral, well shown in the *conchoidal* fracture of obsidian. *Fracture is conspicuous in minerals which do not have cleavage.*

Etching. In no way is the, so to speak, organized nature of a crystal more plainly shown in its susceptibility to etching, or, to the development, by means of acids or alkaline solutions, of regular pits symmetrically arranged and bounded by crystallographic faces. Such etchings serve to determine the system of a mineral, in the absence of crystals, while they also indicate the hemihedral or hemimorphic condition of a crystal, and where two individual crystals are intergrown as in twinning, the individuals can be distinguished by the contrasted etching. Muscovite, first regarded as orthorhombic, by etching figures was shown to be
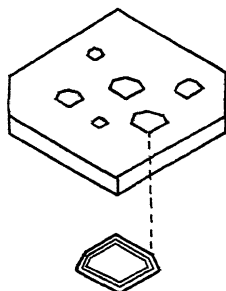
Fig. 264

monoclinic (Fig. 264) ; Barite etched shows different pittings on differently related faces (Figs. 265=Fig. 237) ; the hemimorphic Calamine shows figures with different ends (Fig. 266) ; in Calcite etching with hydrochloric acid gives figures like Fig. 267, with sulphuric acid like Fig. 268. Quartz crystals etched reveal their
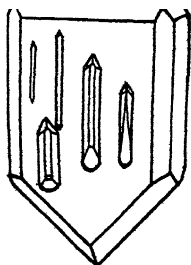
Fig. 266
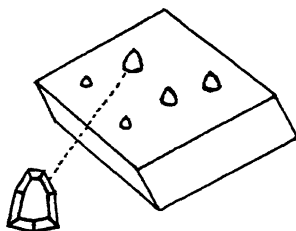
Fig. 267

Fig. 268

two-fold character, as, in the figures developed in the pyramid, two rhombohedrons are indicated, while in right and left-handed crystals the etchings are reversed (Figs. 269, 270=Figs. 238, 239). Natural etchings are found on crystals, and in topaz, and quartz are frequent, sometimes so advanced as to remove portions of the crystal. (Note: The teacher should develop etchings in crystals by etching, using particularly quartz (hydrofluoric acid), calcite, dolomite (hydrochloric acid), and experiment with apatite, orthoclase, barite, halite, etc. To study the etchings a microscope or high power glass will be needed). Solvents of minerals act upon the crystallized substances under the control of the structure of crystallization—thus a ball or sphere immersed in an acid is eaten away unequally in a symmetrical manner, and "in this way it has been proved that those directions along which the greatest corrosion has taken place are nearly perpendicular to the faces upon which etched hillocks are produced, and that those directions along which the least corrosion has taken place are nearly perpendicular to the faces upon which pits are etched; further, that during the corrosion of a sphere certain more or less plane surfaces are developed which are parallel to crystal faces" (Miers). It is a curious fact that minerals disintegrate into dust, and that this, beginning at a point or spot, enlarges, and is delimited by a curved line, a circle or an ellipse, and the position of these figures, on crystal faces, harmonizes with the symmetry of the crystal.

THE OPTICAL PROPERTIES OF MINERALS.

In the relations and behavior of minerals with light, the symmetrical structure and the interior fixed arrangement or order of the ultimate molecules in minerals are perhaps more deeply illustrated than in any other of their aspects. The fundamental phenomena have to do with the bending (refraction) of light rays when they enter the substance of a crystal, the varying velocity of the light rays in the crystal, the peculiar exemption, along certain lines, of the light rays from double bending or refraction, the swerving of the light vibrations, in all planes, to a vibration in one (polarization) plane, the varying of the amount of the refraction for different colored rays, and the results of interference of light waves in different plases, viz, a half or whole wave difference, which develops the most beautiful color effects. (Note: The teacher should carefully rehearse the elementary truths of optics, especially in regard to the phenomena of interference, indices of refraction, reflection, wave length, velocity of transmission in media other than air, etc.)

A fundamental fact in the optics of mineral crystals is the property, or its absence, of double refraction. This at once permits an optical arrangement of crystals into three groups: Crystals which show no double refraction in any direction, as those with *isometric* symmetry; crystals which show no double refraction along one direction, as those with *tetragonal* and *hexagonal* symmetry; crystals which show no double refraction in two directions, as those with *orthorhombic, monoclinic,* and *triclinic* symmetry.

Isometric crystals are called *isotropic;* no matter in what direction the light enters these crystals the ray of light only undergoes simple refraction or is bent from the straight line of its incidence, as in Fig. 256. Light entering tetragonal or hexagonal crystals is doubly refracted, except along one direction *the optic axis,* and these crystals are called *uniaxial.* Light entering orthorhombic, monoclinic, or triclinic crystals is doubly refracted, except
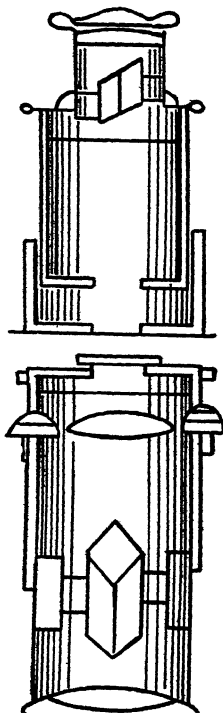
Fig. 271
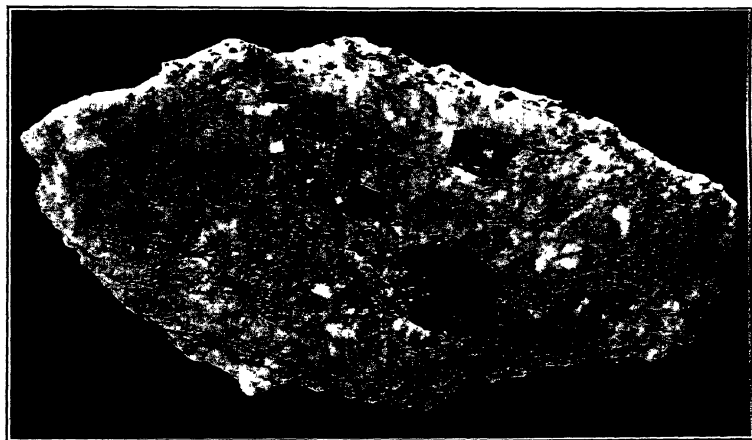
ZINCITE
Franklin Furnace, N. J.
BOLEITE
Boleo, Lower Cal.
Bement Collection, American Museum of Natural History

along two directions, the optic axes, and these crystals are called *biaxial.*

Now practically all optical examinations of natural crystals (usually in thin sections) are made by polarized light and such polarized light may be parallel or convergent and it is usually produced by the passage of ordinary light through a *polarizer* by which the light is polarized. Above such a polarizer in the tube of a microscope is placed another polarizer which however in this position is called an *analyzer:* and between the polarizer and the analyzer the thin section under examination is placed (Fig. 271) upon a stage. The polarizer and analyzer consist of nicol prisms which are made of cleavage rhombohedrons of calcite, three times as long as broad; these are cut as in the oblique plane in Fig. 272, and the halves cemented together with Canada balsam, and the ends are ground plane. This combination insures a ray of polarized light, [two polarized rays, by double refraction, are formed, but one (the ordinary ray) is reflected from the surface of the Canada balsam and absorbed by the blackened side of the prism, the other (the extraordinary ray) passes through] for the exam-
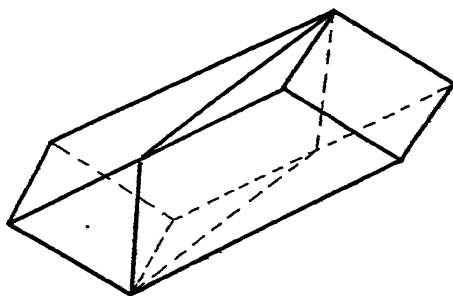
Fig. 272

ination of the crystal sections. Above this polarizer is the analyzei, similarly constructed. When the light passes through the polarizer it is completely extinguished by the analyzer, when the shorter diagonal of the analyzer is placed at right angles to the shorter diagonal of the polarizer, or the *"nicols are crossed."* But this extinction is replaced by light passing through, when a crystal section is inserted between polarizer and analyzer, *if the crystal is not isometric.* Glass and isometric crystals remain darkened, and no light emerges at the analyzer, but generally with sections from all other systems light is seen, while the nicols remain crossed. And

this obviously is because the crystal section is itself *double refract-ing* and twists, so to speak, the light emerging through the polarizer, so that a portion finds its way past the analyzer, as by this tor-sion a component will be vibrating in the plane of the analyzer it-self and so there will be illumination. In no literal sense is there "torsion;" the analyzer actually resolves the light, passing from the polarizer, into vibrating elements *in* and at right angles to its own plane of vibration. The former are of course transmitted. That this is so is evident from the following observations. If a section of a calcite crystal, (which is an uniaxial crystal) cut at right angles to its optical axis (the axis along which there is no double refraction) be inserted between the nicol prisms there is no light seen through the analyzer, but a section cut at some inclination, or parallel, to the optical axis (in the case of calcite its principal or vertical axis) shows light, because such a section is doubly refract-ing. Similarly with biaxial crystals; as in these there are two optical axes along which there is no double refraction, sections cut at right angles to these remain darkened between the crossed nicols dur-ing a complete rotation of the stage. Sections at an angle to these axes or parallel, show light.

But although light passes through sections thus conditioned there is always two positions at right angles to each other in which there is darkness or, as it is called, "extinction," or, at every rota-tion of the stage of 90° in parallel light between "crossed nicols" there is darkness, or four times in a complete rotation. Such ex-tinction lines, determined on faces of crystals, are fixed by the in-clination or parallelism they have for edges of the crystal, and these positions are important in determining the mineral under examination, as these "extinction angles" differ for various minerals, and they maintain a fixed relation to the symmetry of the crystal.

Furthermore it will be observed that a section of an uniaxial or biaxial crystal, not looked through in the direction of an optical axis, produces a *colored* field between crossed nicols. This is due to *interference*. There has been produced by the crystal section by double refraction, two polarized rays or beams; these travel with unequal velocity, one is lagging behind the other, and they are in a condition to interfere and produce color, through the extinction, by interference, of some of the colored rays, but they cannot do so as long as the vibrations are in planes at right angles to each other; this is corrected by the analyzer whose effect is to bring components of each ray into vibration *in the same plane;* then interference takes place, and the crystal section appears colored, the color depending
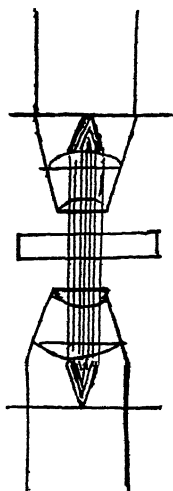
Fig. 273

naturally upon the thickness of the section. If light of one color passed through the section would be dark or light simply in that one color.

With converging light, light converged behind the section in a conical beam of light, (Fig. 273) a striking phenomenon appears; a series of colored curves, which in uniaxial crystals, cut at right angles to the optic axis, are seen as concentric rings, while crossing these rings is a black cross. This cross results from the absence of double refraction along the optic axis of the crystal, and consequently the extinction or absorption of the light in the analyzer in two directions at right angles to each other.

In all other directions there is interference and hence color rings. In converging light in a section cut at right angles to an optical axis of a *biaxial* crystal, a black bar intersecting oval rings is seen.

In the case of a section inclined to the optic axes in a biaxial crystal a very different aspect is given to the slide. The rings become lemniscate, then perhaps unite in an 8-shaped figure, then separate into long arms. Figs. 274-275 show this in thin and thinner sheets of mica, the figure somewhat expanding, as the section becomes thinner, as a longer distance must be traversed by the rays before interference, produc-
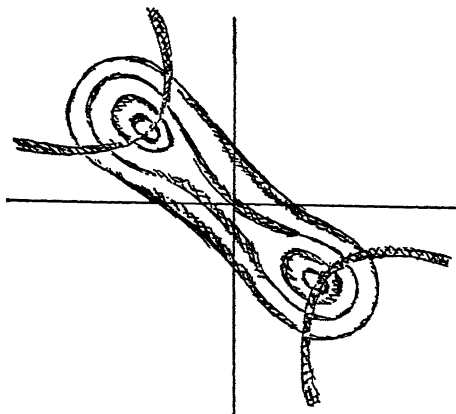
Fig. 274
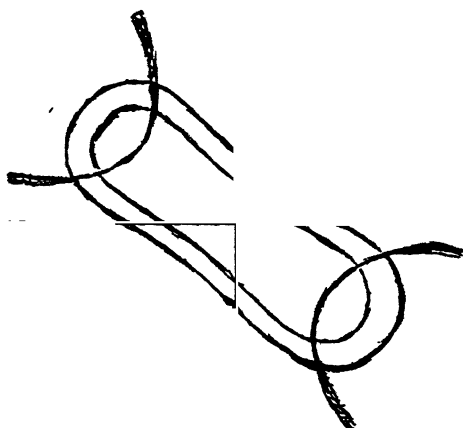
Fig. 275

ing the dark lines, can occur. In such figures there are two opposite centers of reference, about which the lines curve symmetrically; these centers mark the positions of the optic axes and through them in each case a dark hyperbolic curve or "brush" passes.
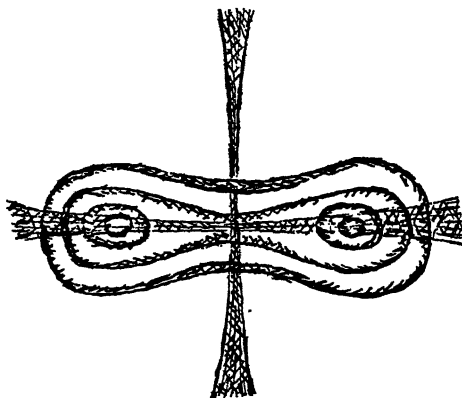
Fig. 276

These two hyperbolic arms become a cross when the line connecting the optic axes, or the optic plane, lies or coincides with either the vibration plane of the polarizer or analyzer (Fig. 276). As the

section is rotated with the stage the optic axes turn too, around the center, and the black cross changes back to the "brushes." Usually in the case of this cross, in biaxial crystals one arm of the black cross is less wide than the other.

The bisectrices of the optic axes, in biaxial minerals, figure in scientific descriptions of the optical properties of minerals, and mineral crystals are, in this respect, distinguished as positive or negative. It will be apparent that the optical axes make, through their intersection, an acute and an obtuse angle, and that both axes lie in the same plane; the line bisecting these angles is, respectively, known as the *acute* and *obtuse* bisectrix. When the acute bisectrix is the line or direction of *least elasticity,* or most refraction, the mineral is called *positive,* when the obtuse bisectrix is so, the mineral is negative. The two bisectrices lie in one plane (plane of the optical axes); they, and a normal to them, constitute the axes of elasticity.

In the double refraction of an uniaxial mineral there is, of course, an extraordinary and an ordinary ray; when the extraordinary ray's index of refraction is greater than that of the ordinary ray, as with quartz, the mineral is positive, when it is less, as with calcite, it is negative.

In the scientific discussion and examination of a mineral the angle made by the optical axes, in biaxial minerals, is determined, and this angle is *apparent* and *real.* The apparent axial angle is the angle between rays moving along the optical axes outside of the crystal; the real, the angle between the same inside the crystal, and, as the rays are refracted, in the substance of the crystal, the apparent angle is more obtuse than the real acute axial angle (Fig. 277).
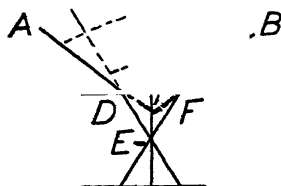
Fig. 277
A C B Apparent Angle
D E F Real Angle
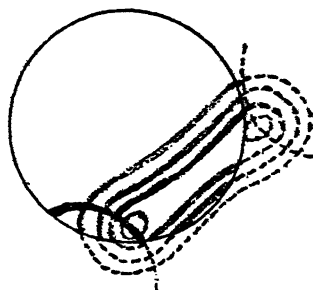
Fig. 278

In a section of a crystal cut perpendicular to the acute bisectrix of the axial angle, and examined in the microscope, between "crossed nicols," the two optical axes are seen as the radiant points of the brushes, but, in a section cut at right angles to the obtuse bisectrix the optic axes are usually outside of the field of vision while it will be noticed that the brushes meet in a cross, and separate into hyperbolas, as the stage is rotated, while in a section parallel to the plane of the optic axes neither optical axis nor the ring system will be seen, but only curved black bands. A section oblique to either the acute bisectrix or the obtuse bisectrix, will produce partial ring systems as in Fig. 278 (Miers).

Further it is to be expected that the optical axes, and hence the axial angle, in the biaxial crystals will be different for different colored light; and they are. This is technically called "dispersion of the axes," and in the orthorhombic system the optical axes, and the curved bands for blue and red light, appear between "crossed nicols," separated from each other along the same line (Fig. 279) in which R. stands for red light, and B. for blue light; while in white light this dispersion effect produces a superimposition of the figures of the single colors, and the brush will lie between B. and R. in Fig. 279 (after Miers). The optical axes are, of course, in one plane, and in the orthorhombic minerals that plane is a plane of symmetry.
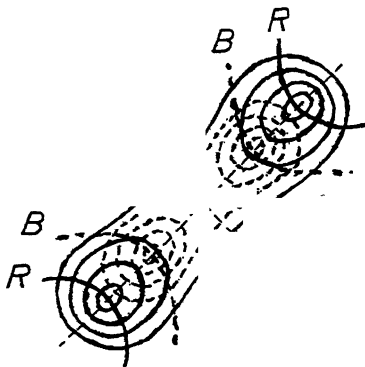
Fig. 279

In monoclinic crystals the dispersion effects are more complicated, and there has been noted "crossed dispersions," (Fig. 280, after Miers), "horizontal dispersion," (Fig. 281, after Miers) and "inclined dispersion," (Fig. 282, after Miers). In the monoclinic
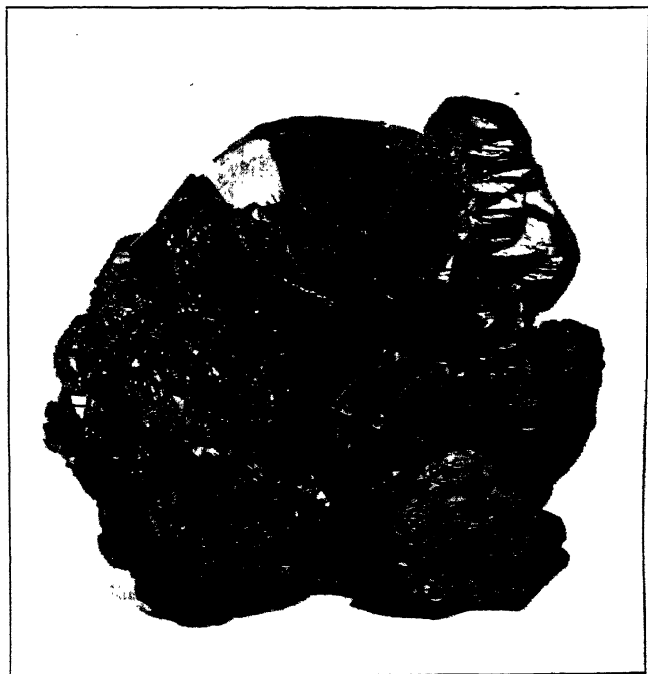
HEMATITE
Rio, Elba, Italy
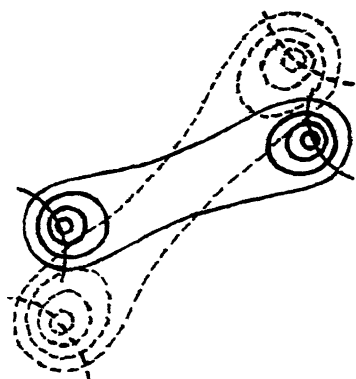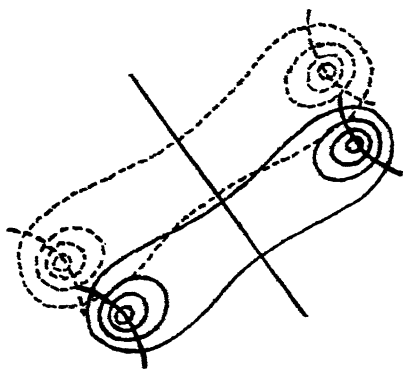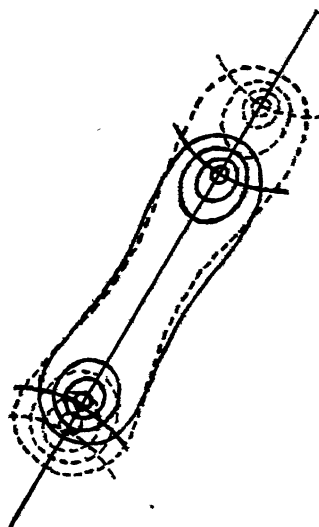
Fig. 280
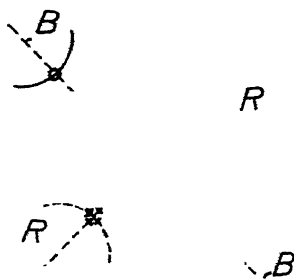
Fig. 281

Fig. 282

Fig. 283

system of natural mineral crystals the bisectrices change, and do not, *as in the orthorhombic system,* coincide with crystal axes, but occupy different positions. The optical axes are in one plane, as always, but these planes, for different colors, are inclined to each

other. It happens in both orthorhombic and monoclinic crystals that the axial plane for one color may be at right angles to that for another; Fig. 283 shows this in an orthorhombic mineral; R. showing the position of the brushes for red light, B. for blue. As red has maximum wave length and blue a minimum wave length with intermediate colors and wave lengths, as green, the optic axes may coincide, and a *uniaxial* effect of colored rings appear.

In triclinic crystals the dispersions of the optic axes and of the bisectrices may be in any direction. Uniaxial crystals are uniaxial for all colors.

An optical feature of extreme interest in crystals is the absorption of different colored rays of light in different directions, giving to transparent minerals different colors. Thus cordierite (iolite) is blue or gray or yellow according to the direction the light enters the crystal. This occurs in doubly refracting media since of the two rays vibrating in planes at right angles to each other, one is absorbed, or partially extinguished, and the other passes through. This is most conspicuous in tourmaline which completely absorbs or extinguishes the ordinary ray, in sections parallel to the vertical axis, and transmits the extraordinary ray alone. This property makes tourmaline a useful means for producing polarized light, as the extraordinary ray it transmits, is of course a polarized ray. This property in minerals of showing different colors as the light, entering the crystal, enters it, and passes through it, in different directions, is called *dichroism* or pleochroism. It forms a useful means of determining minerals, and is valuable in separating some
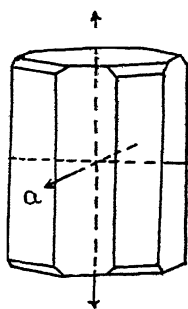
Fig. 284

precious stones as ruby, sapphire, chrysoberyl. Take a crystal, transparent, of Iolite; through the direction of the vertical axis, c, (Fig. 284) the color is yellow, through the macrodiagonal, b, it is blue, through the brachydiagonal a, blue of a different tint; each face however is dichroic or *two-colored* so to speak; if viewed through a *dichroscope* (a long cleavage rhomb of calcite); this instrument gives two images (ordinary and extraordinary) and they will be differently colored. They will be seen through the basal plane, gray and blue, through the brachy-pinacoid light blue and yellow, through the macropinacoid blue and yellow. In uniaxial crystals absorption is in two directions, in biaxial in three. (Note:

The teacher should use the dichroscope, and examine iolite, tour-maline, epidote, corundum, and andalusite. Certain depth of color in natural crystals is necessary for the best results, and the teacher should consult Dana's System of Mineralogy for directions, and fully determine for himself the ocular success before demonstration. The dichroscope, crystals, or sections, for examination, can be bought from the Kny-Scherer Co., New York).

Circular Polarization is the extraordinary property which quartz and cinnabar possess of turning, (rotating), the plane of polarization of the light transmitted along the vertical axis of the crystal. This rotation is considerable. It amounts for each milli-metre of thickness to 33° for blue light, 22° for yellow light, 13° for red light. The effect of this rotation is to bring in the plane of the analyzer between "crossed nicols," a mixture of colors pro-ducing a resultant tint; as when small proportions of red and yel-low light are transmitted, an orange light appears, with the blue extinguished, and if the analyzer is turned in the direction of a clock-hand, green changing to blue, purple and red, successively, are seen. A noticeable effect is the substitution of a colored circle, at the intersection of the black arms of the cross, for the dark center usually seen in sections, between "crossed nicols," cut from uniaxial crystals, at right angles to the optic axis. Artificial salts as sulphate of quinine (tetragonal), thiosulphate of calcium and strontium (rhombohedral), exhibit circular polarization.

As regards right and left-handed quartz crystals (see under Quartz) they effect the rotation of polarized light in opposite direc-tions, and the succession of the colors is exactly reversed. In the right-handed quartzes the succession of colors is red, yellow, green, blue, violet; in the left-handed, violet, blue, green, yellow, red. The colors naturally change in tint with increasing thicknesses of quartz plates placed between the nicol prisms. If a right and left-handed
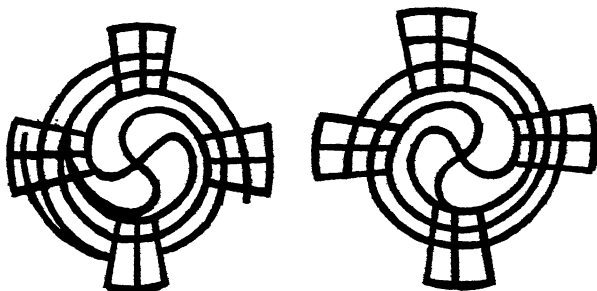
Fig. 285

quartz plate be laid upon each other a dark center is produced, but in place of the straight armed dark cross spiral curves are seen which are known as Airy's Spirals, (Groth), (Fig. 285).

It is quite clear that in a doubly refracting mineral, light travels in different directions with different velocities, whereas in an isotropic or non double-refracting medium it travels in all directions with the same velocity. It is then also clear that in all such directions there is a maximum, a minimum, and a mean velocity of light, and there must be a maximum, a minimum, and a mean refractive index, and in these same three directions there *may be* unequal absorption of light. Such three directions (axes of elasticity) are critical factors for the determination of a mineral, and their value and positions enter into the scientific description of a mineral; are indispensable. The direction of maximum velocity is the direction of the least refractive index, and the direction of minimum velocity is the direction of the greatest refractive index. Two of these directions may, as in uniaxial crystals become the same *expressed in length.* These three directions form the axes of a geometrical ellipsoid—the *indicatrix*—which (Fig. 286) has the property of furnishing (through its construction), in its sections, the refractive indices for the beams of light in a crystal and the planes in which the latter are polarized. (Note: The teacher might consult larger works for instruction upon the *indicatrix* and *Fresnels ellipsoid,* notably Prof. Henry A. Miers' Mineralogy; an Introduction to the Scientific Study of Minerals; Macmillan & Co.).
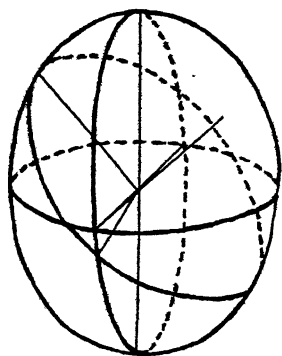
Fig. 286

Optical Anomalies are those variations from apparent optical laws which many minerals display, and which often lead to a more accurate knowledge of their crystallographic construction.

Thus some isometric minerals show double refraction, while some uniaxial crystals become biaxial; Garnet (isometric) shows double refraction, which has been assigned to the twinning of triclinic individuals, also Leucite (isometric), which has been explained by referring this seemingly cubic mineral to the tetragonal system. Chabazite (rhombohedral) possesses optical characters which have led to an hypothesis of twinning triclinic individuals. Apophyllite (tetragonal) shows biaxial phases; increase of temper-

STOLZITE

Broken Hill Mines, New South Wales

Bement Collection, American Museum of Natural History

1 inch

HEMATITE

St. Gothard's, Switz.

ature in many crystals alters optical habit, as in Analcite, in which *dry* heat develops double refraction, and thus it appears that the optical anomalies of this mineral are connected with loss of water, which normally in Analcite reaches over 8 per cent.

Optical Anomalies are connected with *pseudosymmetry,* which is the assumption of a higher order of symmetry by crystals really lower, through their mimetric juxtaposition or twinning by means of which they preserve a resemblance to a different system. Thus the union of three crystals of Aragonite (orthorhombic), produces the effect of an hexagonal prism. (Fig. 287). Similarly, leucite which appears isometric (Fig. 288), would be made, by the measurements of von Rath, to be tetragonal. Later observations proved Leucite not to be uniaxial but biaxial and orthorhombic, and it appeared that when heated this extraordinary mineral became truly isotropic and cubic. Boracite, apparently cubic, and tetrahedral, "is composed of six or twelve pseudo-cubic 'sub-individuals' which interpenetrate each other more or less completely and have their acute bisectrices perpendicular to the dodecahedral faces" (Miers). (Note: The teacher should show in the microscope between "crossed nicols," the interesting pseudosymmetry of aragonite, the irregular extinction of different sectors and the lemniscate curves and brushes indicating its biaxial character. This is seen in a thin section perpendicular to the vertical axis in a pseudo-symmetrical crystal, such as the familiar ones from Sicily).
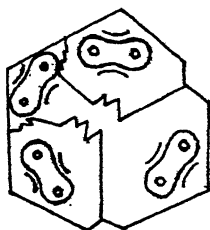
Fig. 287
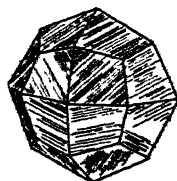
Fig. 288

Twinning of crystals, pseudosymmetry, inclusions, etc., are detected in a beautiful way, in thin sections examined in parallel polarized light, through the difference in brightness or color in the different sections of the compound crystal. If the section is perpendicular to the twinning plane, a symmetrical extinction direction to the same is observed (Fig. 289, hornblende); if the twinning is repeated (polysynthetic), alternating black and light stripes are seen

(Fig. 290) or contrasted colors; if the crystal is variously con-
structed of individuals, these may be seen, as in Fig. 291, or, if
more regularly united, as in Fig. 292, (labradorite, twinned in two
ways).
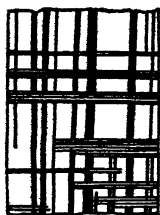
Fig. 289   Fig. 290   Fig. 291
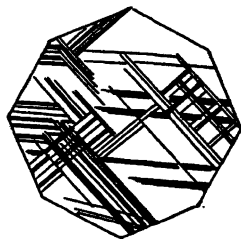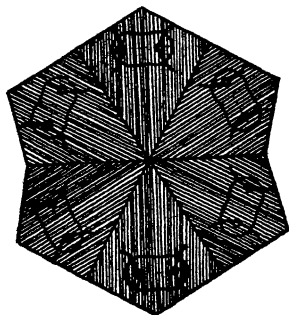
Fig. 292   Fig. 293

To produce color effects more strikingly in such sections, plates
of quartz or gypsum are introduced above them in the microscope.
In convergent light the elementary crystals may display axial fig-
ures (Fig. 293, aragonite).

Mica films piled on each other, successively reversed in posi-
tion, yield an uniaxial effect with the black cross and the color rings,
although mica is biaxial.

Double Refraction is developed in amorphous bodies, as glass,
by pressure and torsion, and anomalous double refraction in isotropic
crystals has been referred to internal strain.

Fluorescence is an optical property of minerals especially well
shown in Fluorite. Cornish fluorites in transmitted light appear
sea-green, while in reflected light they are a beautiful violet-blue.

Thus in a darkened room such a specimen is illuminated, by a ray of light allowed to fall upon it, with a blue color, which however ceases at a moderate depth, within the crystal, and the light thus passing through fails to evoke the blue upon entering a second surface of the same mineral held underneath it. The fluorite is said to fluoresce blue, and this peculiar property seems to be derived from the presence of hydrocarbons.

By a blow, rubbing, scratching, trituration, light effects are produced in minerals as blende, some dolomites; while under heat fluorite, topaz, pectolite, apatite, phosphoresce. (Note: The teacher should endeavor to demonstrate the optical properties of mineral crystals, and minerals, in the class-room, and drawings in colored chalk on the blackboard will be found helpful in showing the birefringence of doubly refracting minerals. A polarizing microscope is indispensable).

CRYSTALS

When minerals are found as crystals the crystallographer, for their proper determination and drawing must determine their faces, the angles between them, and express the relations of these faces in symbols, (such as we have partially noted), and discover the kind and number of *forms* on each crystal as prisms, pyramids, domes, etc., or the cubic forms of the isometric system. These forms are recorded and, gradually, as the results of examination accumulate, as more and more crystals of the different species are studied, the habit of each mineral is more and more fully understood.

The points of reference fixing such faces of crystals are their relations to the axes, and these are expressed in the so-called indices or parameters, which mean *relative* points of intersection, by the faces, of the axes of the crystal and such *intercepts* are related to each other by a simple law, that the smaller divided into the larger ones give simple rational numbers or infinity or zero. In other words the axes are cut by the faces at distances from the center of the crystal, (the point where the axes intersect), which are related to each other as ½, 1, 2, 3, etc., or, a face may be parallel to an axis, when such an intercept becomes infinity.

The *ratio* of the axial intercepts is alone important. Of course all crystals of one mineral are to be referred to *one* and the *same* system. The various examples of crystals in the same species of minerals, while different between themselves, present new crystallographic *forms* of the same system and all will be found included under one systematic law. The angles between crystal faces
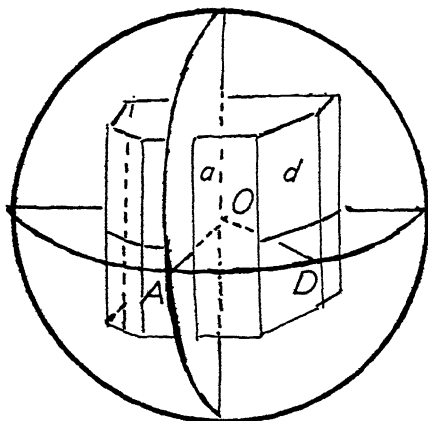
Fig. A

are determined by an instrument called a Goniometer, (angle-measure), and the principle involved is the catching of a reflection (signal) from the center or pole of one face, and then, by turning the crystal, a companion reflection from the center or pole of the adjoining face, whose angle with the first it is desired to know. The angle thus fixed will really be the supplements of the actual interfacial angles. Thus in Fig. A. the angle AOD, measured by the goniometer, is the *supplement* of the angle between the faces *a* and *d*.

Crystal drawings are not true perspective drawings. They are drawn as if the eye and the crystal were at an infinite distance from each other, or, as Prof. Lewis ·expresses it: "the crystal is drawn in much the same way as it would appear, if viewed through a telescope adjusted for a very distant object."

There are two sorts of crystal drawings, *orthographic* and *clinographic*. In the former the more important edges or faces of the crystal are inclined at an angle (the latter chosen) to the paper, which receives the drawing, in the latter the vertical axis of the crystal is *in* or *parallel to* the paper, while the crystal is rotated 18° 26′ to the right and the eye of the observer is supposed to be 9° 28′ above the top of the crystal. Drawings of crystals are usually clinographic. This method gives solidity and an apparently true perspective. There are also orthogonal projections of crystals in which there is a plan of the crystal on a horizontal plane, and an elevation on a vertical plane.

Preliminary examination of a crystal may determine its system, and a free-hand drawing enables the observer to determine the general assemblage of forms, from which a principal one is chosen. This simple form is completely drawn, a hard pencil being used; in introducing the faces of the other *forms* on the crystal care must be taken to "cut off proportional lengths on all homologous edges." *Plans* of tetragonal, hexagonal, orthorhombic or isometric crystals can be readily made, for the faces vertical to the plane (hori-
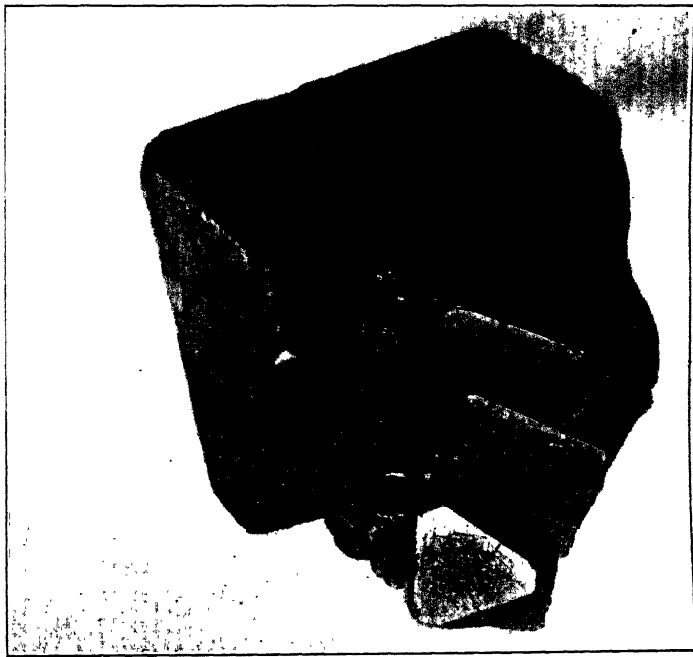
SPINEL

Monroe, Orange Co., N. Y.

Bement Collection, American Museum of Natural History

zontal) of the paper, when by measurement the angles between such vertical faces are known; *zone* faces can be drawn in by inspection of the crystal, and "their distance from one another should
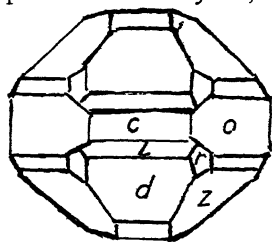
Fig. B

approximate to the impression of the width of the faces when the crystal is looked at endwise." Zone faces are those whose intersections form sets of horizontal lines. (In Fig. 145 XSM is a zone, TLM is another, PLS is a third) Fig. B is a plan of a barite crystal, the outlines represent the intersection of the paper by the vertical planes bounding the crystal, *c* is the base; across the plan, from right to left and from the bottom to the top, are seen parallel edges, the faces bounded by these constitute zones. But a number of edges, as those between *zd, ro, lr* require the *indices,* the proportional intercepts on the axes, of the faces bounded by them, before they can be drawn. These are found sometimes by what is called *linear projection,* but the symbols of the faces and the parameters can be calculated from the measured angles of the crystal. Divergences beyond those due to observation are met with in the angles between corresponding faces, and experience and judgment is requisite to select the angles to be used in the computation of elements, and the theoretical angles.

The "axial cross" is first constructed (see Moses & Parsons, Chap. X, pp. 75, 77, 78), and the determination of the direction of the edges follow (*ibid*).

It is clear that the measurements of the angles between faces of a crystal besides being necessary for its drawing, also lead to the discovery of new forms hitherto unknown to the mineral species under examination. The solution of the crystals under the several systems involves a knowledge of Analytical Geometry and works of extreme elaboration discuss them (see A Treatise on Crystallography by W. I. Lewis. To acquire facility in drawing clinographic projections of crystals, the teacher should practice the pupils in examples and methods given in a book of Margaret Reeks, called Hints in the Drawing of Crystals (Longman, Green & Co.)).

DETERMINATIVE MINERALOGY

All minerals present to us a series of combinations of the elements, which combinations chemistry investigates, finds out the

exact amounts of the elements involved in each combination, and from that determination deduces or constructs a formula which so exactly expresses the constitution of the mineral as to allow the student to tell the percentage of each ingredient in the salt or compound considered. For instance, the familiar mineral pyrite is composed of sulphur and iron in the proportion of 53.3 parts of sulphur to 46.7 parts of iron in a hundred, and chemistry expresses this by a symbol, FeS_2, in which Fe is iron and S sulphur. Chemistry gives us an *atomic weight* for the iron atoms, which is 55.8, and for the sulphur atoms, which is 32. In a compound where there is 53.3 parts of sulphur and 46.7 parts of iron, the atomic weight is therefore for iron and sulphur 1 and 2, and the formula FeS_2 expresses that ratio; and because it expresses this quantitative relation the formula can be taken as a basis for computing the percentage of composition. Thus,

$$1 \text{ atom of iron,} \quad Fe = 55.9$$
$$2 \text{ atoms of sulphur,} \quad S_2 = 64$$

$$\text{Total atomic weight,} \quad 119.9$$

Of which one atom of iron (Fe) represents 46.7 per cent and two atoms of sulphur (S_2) represents 53.3 per cent. Throughout mineral cabinets formulæ of this and similar character are frequently given for the different species, and they express in an identical manner the atomic ratio of the chemical constituents in each species and afford a direct clue, as shown above, to the percentage of composition for each element in any mineral. The following list gives the symbols used in chemistry for the different elements and their atomic weight; or more correctly, the *comparative* atomic weights, since in no instance is it assumed that it can be known what is the actual weight of an atom. Taking the atomic weight of the element hydrogen as unity (1), the atomic weights of the other elements are represented as such multiples of that as the numbers opposite their symbols indicate. In the list a division is made of the elements into certain groups, as Non-Metallic, Semi-Metallic, and Metallic, which will be found convenient for the explanations which follow. These groups are again subdivided into subordinate sections according to the chemical affinity of their members.

NON-METALLIC.

	Symbol	At. Weight		Symbol	At. Weight
Hydrogen	H	1.	Carbon	C	12.
Oxygen	O	16.	Phosphorus	P	31.
Nitrogen	N	14.	Selenium	Se	79.2
Bromide	Br	79.96	Tellurium	Te	127.6
Chlorine	Cl	35.45	Silicon	Si	28.4
Fluorine	F	19.0	Sulphur	S	32.
Iodine	I	126.97	Boron	B	11.0

SEMI-METALLIC.

	Symbol	At. Weight		Symbol	At. Weight
Antimony	Sb	120.	Vanadium	V	51.1
Arsenic	As	75.0	Bismuth	Bi	208.0

METALLIC.

	Symbol	At. Weight		Symbol	At. Weight
Potassium	K	39.15	Manganese	Mn	55.0
(Kalium)			Iron (Ferrum)	Fe	55.9
Sodium (Natrium)	Na	23.	Cobalt	Co	59.0
Lithium	Li	7.	Nickel	Ni	58.7
Rubidium	Rb	85.5	Chromium	Cr	52.1
Caesium	Cs	132.9	Molybdenum	Mo	96.
Calcium	Ca	40.1	Tungsten	W	184.
Strontium	Sr	87.6	(Wolfram)		
Barium	Ba	137.4	Uranium	U	238.5
Beryllium	Be	9.1	Tin (Stannum)	Sn	119.0
Magnesium	Mg	24.26	Titanium	Ti	48.1
Zinc	Zn	65.4	Zirconium	Zr	90.6
Cadmium	Cd	112.4	Thorium	Th	232.5
Lead (Plumbum)	Pb	206.9	Tantalum	Ta	181.
Thallium	Tl	204.1	Niobium	Nb	94.
Copper (Cuprum)	Cu	63.6	Gallium	Ga	70.
Silver (Argentum)	Ag	107.93	Germanium	Ge	73.5
Mercury	Hg	200.0	Gold (Aurum)	Au	197.2
(Hydrargyrum)			Platinum	Pt	194.8
Yttrium	Y	89.	Iridium	Ir	193.0
Ytterbium	Yt	173.0	Osmium	Os	191.
Cerium	Ce	140.25	Ruthenium	Ru	101.7
Lanthanum	La	138.9	Rhodium	Rh	103.0
Erbium	Er	166.	Palladium	Pd	106.5
Aluminum	Al	27.	Scandium	Sc	44.1
Indium	In	115.0			

· While a few native elements are found on or in the crust of the globe, the larger part of mineralogy has been constructed from the various unions of these elements into binary (twofold) and ternary (threefold) compounds. An example of a binary compound would be the sulphide of iron—pyrite—mentioned above, consisting of the direct union of two elements, sulphur and iron, and related to each other chemically as negative and positive; lime, calcium and oxygen, would be also a binary compound. A ternary compound would be a union of three elements chemically different, as the sulphate of lime, where we have *first,* sulphur, oxidized to an acid radical by union with the *second* element oxygen, and the sulphuric acid thus made has combined with the *third* element, the base calcium. Alum, the sulphate of potash and alumina ῾would also be regarded as a ternary compound, its apparent fourfold (quaternary) character being resolved into two ternary unions, the sulphate of potash and the sulphate of alumina.

The union of the non-metallic and semi-metallic elements with the metals by direct union, forms compounds known as the antimonides, the arsenides, the tellurides, bismuthides, sulphides chlorides, fluorides, bromides, and iodides, phosphides (not known in terrestrial mineralogy but occuring as phosphide of iron and nickel, schreibersite, in meteorites), selenides, and oxides. Some of the former of these are combined in dual unions, and form the sulph-antimonides, sulph-arsenides, etc., which are the united compounds of sulphides and antimonides, sulphides and arsenides, etc. Oxygen combines universally with the other elements, and in the case of the metals forms the oxides, while with the non-metallic and semi-metallic elements it forms the acids, in conjunction with water, which again by further union with the bases form the sulphates, phosphates, nitrates, borates, arsenates, antimonides, vanadates, etc., and, more importantly than all, the silicates.

The silicates are a vast group of mineral compounds embracing the larger portion and the more widely distributed portion of minerals, and those compounds have been interpreted and classified into a series of sub, mono, and di-silicates, on the assumption of an *oxygen ratio,* between the acid and basic elements. This *oxygen ratio* is briefly explained as follows: it is the ratio between the number of oxygen atoms in the different oxygen compounds present in a mineral. Silicon unites with oxygen, forming an acid or negative radical silica; this silica unites with the earthy and metallic bases, the oxides formed from the metallic elements given above, and these silicates have a ratio of the oxygen of the bases to the oxygen of the silica, which establishes their serial position.
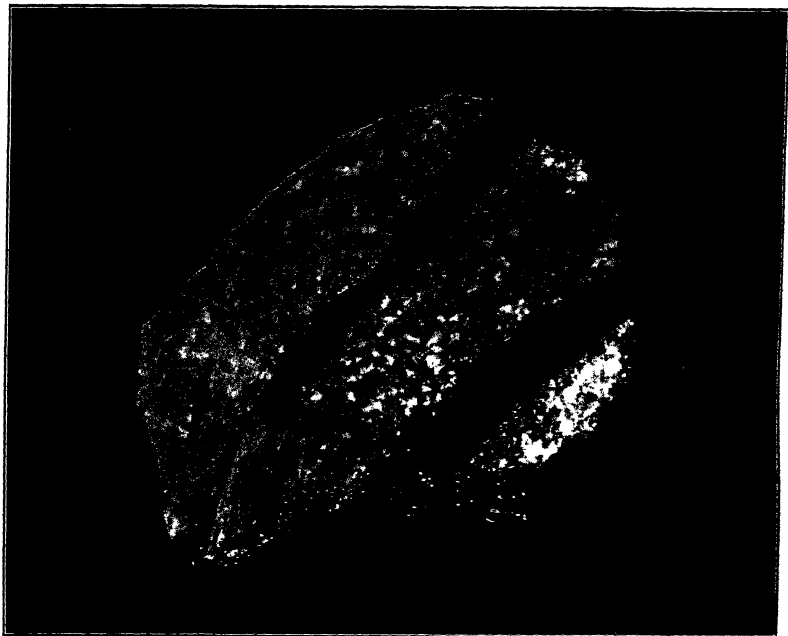
RUTILE IN QUARTZ
Lynchburg, Va.
Bement Collection, American Museum of Natural History

MAGNETITE
Binnenthal, Switz.
Bement Collection, American Museum of Natural History

Thus when the number of oxygen atoms in the base are half what they are in the silica, the compound is called a *bisilicate,* when the same a *unisilicate,* and when more a *subsilicate.*

In beryl, for instance we have the formula which expresses its composition, $3BeO$, Al_2O_3, $6SiO_2$, in which the oxygen of the bases beryllium and aluminum numbers *six* atoms, that in the silica *twelve.* It is a bisilicate. For Willemite, the silicate of zinc, the formula is $2ZnO$, SiO_2, in which the oxygen of the base zinc numbers two atoms, that also of the silica two atoms, or they are the same; the ratio is $1 : 1$ and the compound is a unisilicate. Similarly in sub-silicates the number of oxygen atoms of the bases exceeds that of the silica.

Minerals are frequently grouped into *hydrous* and *anhydrous* sections, which refer to their combination with water or not. Sometimes this water is regarded as a base and the difference of opinion in regard to its exact character in some instances leads to varying classifications. Labels throughout collections indicate the divisions of chemical compounds to which the minerals following or with them belong.

POLYMEROUS COMPOUNDS.

These compounds are found in vegetable and animal organisms, and consist in union for the most part of oxygen, hydrogen, nitrogen and carbon. These unions are infinitely varied and the innumerable compounds found in coal tar, in the tissues of plants and animals, and in the mineral world, in natural waxes, oils and pitches, belong here. These compounds are grouped into series which have a uniform type of composition, and they are further broadly divided into oxygenated and non-oxygenated compounds. An example of the former is amber, consisting of carbon 78.94, hydrogen 10.53, oxygen 10.53, and one of the latter, native paraffin (ozocerite), consisting of carbon 85.47 and hydrogen 14.57.

These compounds reach a very high degree of complexity in nature, but those which are considered in mineralogy are not so numerous nor usually so elaborately constituted.

Minerals are chemically determined in the chemical laboratory, and the percentages of their various constituents determined, and from such a purely proportional statement their so-called "empirical formulas" are constructed. As an illustration take the analysis of the feldspar Albite. The chemist furnishes this analysis, Na_2O, 11.8, Al_2, O_3, 19.5, SiO_2, 68.7, where we have soda, alumina, and Silica, (quartz or sand). To develop the "empirical formula," divide the percentage of Na_2O by the atomic sum of Na_2O, (obtained from

the table of atomic weights), or 62. which gives .1903. Similarly the Al_2O_3 gives .1911, and the SiO_2 1.145, and the ratio between these is 1. 1. 6. about one of Na_2O, one of Al_2O_3, and six of $SiO_2 = Na_2Al_2Si_6O_{16}$ or reduced to its simplest terms, $NaAlSi_3O_8$; and, as there are four oxygen atoms in the bases and twelve in the silicic acid, the salt is a trisilicate.

The chemical theory of a salt is the union of a base with an acid, the former replacing the hydrogen, or basic, atoms of the latter. Thus the formula of nitric acid is HNO_3, and the nitrates of sodium, potassium, (sodium and potassium being monads or equivalent in replacing power to one atom of hydrogen) are written $NaNO_3$, KNO_3. But in the case of a dyad as calcium or barium it will require two molecules of the acid to furnish the necessary replaceable hydrogen atoms and the formulæ are written $Ca(NO_3)_2$, $Ba(NO_3)_2$. Mineralogy to explain the constitution of many natural salts, *or minerals,* has assumed the existence of a number of acids as sulpho-acids; example, $H_3AsS_3, H_3SbS_3, H_3BiS_3$, and the oxy-acids, nitric HNO_3, carbonic H_2CO_3, sulphuric H_2SO_4, tungstic H_2WO_4, aluminic $HAlO_2$, boric HBO_2, phosphoric H_3PO_4, tantalic $HTaO_3$, and various silicic acids as disilicic acid $H_2Si_2O_5$, polysilicic acid, $H_4Si_3O_8$ metasilicic, $H_2Si_2O_3$, orthosilicic H_4SiO_4 which may frankly be considered as hypothetical simply.

A salt is acid when all the hydrogen atoms are not replaced by the base, basic when the replacing base exceeds them, as in malachite (carbonate of copper) which may be considered as a carbonate of copper combined with the hydrate of copper and can be written $CuCO_3$, $Cu(OH)_2$.

Water, as *water of crystallisation,* and driven off at a temperature of 100° C. or 212° Fah., and *water of constitution,* only expelled at a red heat, enters extensively into the chemical constitution of minerals; and groups of minerals are divided into hydrous and anhydrous series on that account.

One of the interesting and important features in mineral constitution is the replacing power of equivalent elements. Minerals are seldom pure, and adventitious mixtures or inclusions of other minerals mar or vitiate analyses, while slight traces of elements foreign to the make-up of the mineral under examination give its industrial results novel values. Thus the magnetite (an iron ore, the protosesquioxide of iron) of the New York Adirondacks contains perceptible quantities of tungsten, titanium, vanadium, cobalt and nickel. But the so-called "vicarious" constituents of a mineral are really involved in its chemical formula, replacing each other, while the mineral retains its crystallographic identity. The oxides CaO,

MgO, FeO, do this, also Al_2O_3, Fe_2O_3, Cr_2O_3, the sesquioxides, in the mineral garnet; and so five different varieties of garnet arise, or calcium-aluminum, magnesium-aluminum, iron-aluminum, calcium-iron, and calcium-chromium garnets. This principle of replacement is also illustrated in the pyroxenes and amphiboles which differ very remarkably in composition but can have their chemical structure, or composition, as far as relates to the relations of groups of radicles composing it, expressed in a general formula.

A deeper physical principle connected with replacement is isomorphism, the crystallographic resemblance of certain similar chemical compounds, and the similarity of minerals whose bases are chemically allied metals. As illustrating the former it was long ago pointed out by Mitscherlich that the carbonates of calcium, magnesium, iron, zinc and maganese crystallized in one system (rhombohedral), while among minerals the sulphides of antimony, bismuth and arsenic are orthorhombic, and each one of these bases crystallizes again in one system, the rhombohedral. It is irresistibly enforced by the study of mineral composition that acid radicles and many bases replace each other in identical crystal forms, though it should also be remembered that this consanguinity does not mean identical physical properties, as hardness, optical features, extensibility, etc. This power of replacement or mixture is probably quite widely shown, and the term "solid solution" has been devised to indicate the absorption and digestion by a mineral salt of another mineral salt of isomorphic relations, without change of crystallographic form. Isomorphism among minerals and chemical compounds has excited much attention, and the limits of its meaning has been much extended. Minerals approaching each other closely in form without exact identity have been called *homomorphic,* and this has been carried so far, that minerals of similar composition, but of very different forms, have been considered (Rammelsberg), isomorphic if these forms are connected by rational relations, as in the proportions of their axial lengths; and A. Laurent has urged that two minerals may be isomorphous if they show similarity of form, and has pushed his views so far as to break down the insulation of the crystal systems themselves. All minerals in the isometric system might be called isomorphic as the angles between faces are invariable, but isomorphism could here be limited by identity in cleavage, or in twinning law. A very certain index of isomorphism is the facility of two salts to crystallize together, and build an homogeneous individual crystal, as with carbonate of calcium and carbonate of magnesium. Again a crystal of chromealum (wine colored) will grow on in a solution of potassium alum

(colorless), which is a radical proof of isomorphism. Minerá groupings as they are made by mineralogists have reference to a exact or approximate isomorphism. (Note: The teacher shoul devote some time to elucidating a few primary chemical conception: or ideas: chemical atom, chemical molecule, chemical affinity, sym bols and formulæ, acids, bases, salts, classification of elements gases, liquids, solids, solubility, insolubility, precipitation, volatiliza tion, reaction, graphic symbols, valency, organic, inorganic, decom position, oxydation. This instruction should be lengthened over sev eral or many hours, with drawings on blackboard, demonstratio with chemicals, but especially along the lines of mineralogical in vestigation).

THE BLOWPIPE.

Minerals when found in the field or submitted for identificatio should first undergo a physical examination, as to hardness, specifi gravity, luster, and optical features. The first can be fairly we determined by the knife, in conjunction with specimens of the scal of hardness (p. 64) which, as they are successively scratched b the piece of mineral tested, show its superior hardness. The specifi gravity must be made out by weighing. (Note: The teacher shoul demonstrate or describe the methods of specific gravity determina tion for objects lighter and heavier than water, and for liquids, an soluble material and for pulverulent or dust bodies), or it can b approximately determined by heavy solutions in which the minerá floats or is *in equilibrio,* or sinks. In the first instance it is lighte than the liquid, in the second it has the same specific gravity, in th third it is heavier than the liquid. These solutions are Methylen iodide, sp-gr. 3.3: this can be diluted with benzol and its gravit reduced to 0.98, and this mixture can be allowed to stand until graduated solution (lighter at the top, heavier at the bottom) i obtained, in which the minerals tested will float at different levels Besides these there is Thoulet's solution of *potassium-mercury io dide,* which by admixtures, with water may assume all specific grav ities between 3.196 and 1. Of course by comparison of the be havior of the mineral tested, with that of fragments of minerals o known specific gravity, in the same solution a very good idea i obtained of its gravity. Thoulet's solution has a sp. gr. of 3.196 Klein's, (*cadmium borotungstate*), of 3.28, Rohrbach's, (*barium mercuric iodide*), of 3.58. *Thallium silver nitrate* has a specifi gravity of 5. forming a clear liquid at 70° Fah.

Table of specific gravities.

0.6 - 1.00   Petroleum, wax, water.
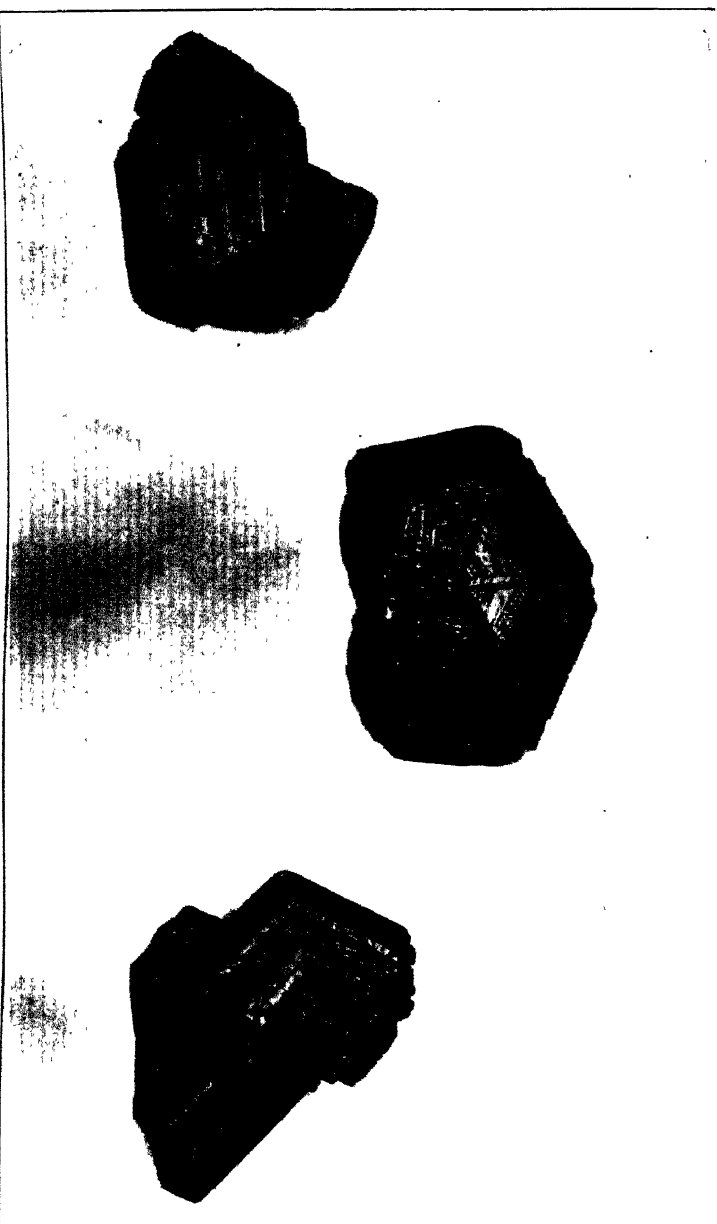
RUTILE
Parksburg, Pa.

Bement Collection, American Museum of Natural History

1.0 - 1.5	Pitch, coal, soda, glauberite.
1.5 - 2.0	Alum, borax, salt petre, sulphate of iron.
2.00- 2.5	Gypsum, leucite, graphite, sulphur.
2.5 - 2.8	Quartz, feldspar, nephelite, beryl, serpentine, talc, calcite.
2.8 - 3.0	Aragonite, dolomite, anhydrite, tremolite, mica.
3.0 - 3.5	Fluorite, apatite, hornblende, augite, olivine, epidote, tourmaline, topaz, diamond.
3.5 - 4.0	Siderite, malachite, azurite, limonite, corundum.
4.0 - 4.5	Barite, rutile, chromite, chalcopyrite, sphalerite.
4.5 - 5.5	Hematite, pyrite, marcasite, stibnite, tetrahedrite.
5.5 - 6.5	Magnetite, cuprite, arsenopyrite, chalcocite, proustite.
6.5 - 8.0	Cerussite, cassiterite, galena, argentite, iron.
8.0 -10.0	Cinnabar, copper, bismuth.
10.0 -14.0	Silver, lead, quicksilver.
15.0 -21.0	Gold, platinum.
21.0 -23.0	Iridium.

The hardness and specific gravity determined, the luster may help out the characteristic properties of a mineral under examination. The metals and metallic compounds have a metallic luster quite usually, the silicates a vitreous. Test it with hydrochloric acid, and look for effervescence which shows it to be a carbonate. The optical properties are not so easily estimated, but if a microscope with nicol prisms is used, small pieces of the mineral on a glass slide can be used to fix its refractive nature, whether isotropic (isometric) or doubly refracting, and in converging light whether mono or biaxial.

The blowpipe is a convenient and serviceable assistance: a great deal can be made out with it, and while it admits of being used quantitatively, its practical use is almost solely confined to qualitative tests.

The blowpipe lamp (Fig. 294) is an oil (preferably rapeseed) lamp, whose flame is manipulated by a blowpipe (Fig. 295) so as to produce two kinds of flames, a *reducing* and an *oxydizing* flame. The former can generally be made by holding the blowpipe outside of the flame of the lamp, and turning the latter over by the air current through the tip of the pipe. It is a yellow, smoky, highly hydrogenous flame, which takes up oxygen, and reduces oxides to their metallic bases, or has that tendency. The oxidizing flame— more easily produced—arises when the pipe is inserted in the flame of the lamp, and a current of air, rapidly blown through, converts it into a blue, intensely hot flame, which oxydizes the metals and
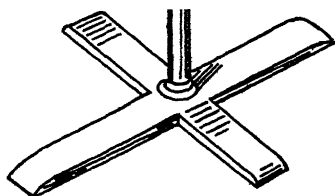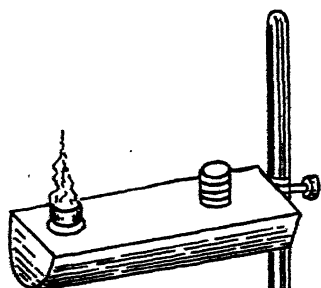
Fig. 294   Fig. 295

roasts the sulphides, and is applied to test the fusibility of the mineral tested. A perfect test of the successful working of the reducing flame is when the operator can render the deeply amethystine bead of manganese (in the oxydizing flame) in borax *colorless;* and of the oxydizing when the yellow or opaque brown borax bead (in the reducing flame) of molybdic acid, is reciprocally made by it, colorless.

In connection with the blowpipe and lamp there is used some simple reagents (principally borax, microcosmic salt, carbonate of

soda, nitrate of cobalt, bismuth flux); some additional apparatus as charcoal, a platinum wire and foil, pincers, an alcohol lamp, and glass tubes ($\frac{1}{4}$ in. diameter); which latter are cut into small lengths (2 in.), and used as *open* tubes, or *closed;* when the glass is drawn out in the alcohol lamp flame, and the tube becomes sealed at one end.

If the mineral is a compound of sulphur, antimony, arsenic, or tellurium with a base, its conduct in the heating flame is characteristic. It gives off vapors which can be recognized: the brimstone odor of sulphurous acid, the white fumes of antimony, garlic odor of arsenious acid, and on charcoal, for tellurium compounds, a white coating burning green in the reduction flame. A metal base determined, the borax or microcosmic salt bead in a loop in the platinum wire will be used for its identification: as that with borax in oxydizing flame, blue is given for cobalt; orange to yellow for chromium; violet, (hot), brown (cold), for nickel; amethyst, for manganese; green (hot), blue, (cold) for copper; and so on. (Consult Brush's Determinative Mineralogy and Blowpipe). These colors vary with the different reagents and are modified by the different flames, oxydizing or reducing.

Fusibility is easily tested, and will vary from the most easily fused stibnite to the utterly infusible corundum. The charcoal, as a support for the mineral tested, will affect a reducing influence on metallic compounds, and the white, red, yellow, bluish coatings formed in the sublimation of the tested material afford guides to its detection. In the open tube when a current of air is passing over the heated test, sublimates may be drops of tellurium oxide, crystals of arsenious acid or of antimony oxides or of bismuth. In the closed tube the unoxydized sublimates may be water, mercury drops, mirrors of metallic arsenic, sulphur beads, reddish sublimates of antimony oxy-sulphide, or yellow of arsenic sulphide, all of which point the way to the detection of the compound. The color produced in the residue, left on the charcoal by heating, with nitrate of cobalt may be red, blue, violet, green, indicative of magnesium, aluminium, zirconium, zinc, or tin. The metallic bases as copper, lead, silver, are yielded, by easily reducible salts on the charcoal, with carbonate of soda, as malleable buttons. The hydrated nature of a mineral is quickly seen when on heating the material in a closed tube water vapor is disengaged and condenses in drops. Some hydrated minerals (zeolites, jefferisite, vermiculite) swell and exfoliate or even bubble from the escape of the steam. (Note: The teacher should dwell on blowpiping at considerable length. A cheap and useful blowpipe can be made from a white clay pipe, with its bowl stopped

with a cork through which passes a glass ($\frac{1}{4}$ in.) tube, drawn out to a fine point, which when snipped off with tweezers, leaves a useful orifice. If this is smooth and even a good flame is secured. A candle makes a good lamp. All the reactions in Brush's Blowpiping should be gone through with, and some twenty representative minerals, afterwards, determined. The teacher *must* consult Cornwall's Plattner).

THE OCCURRENCE OF MINERALS.

Minerals, as inorganic bodies or salts, make up the rock portion of the earth's crust, and in this sense, even when unindividualized, massive, or compact, are found at any point where rock emerges on the surface, or, in the detrital and abraded accumulations which form the shore beaches, the clay beds and even the soils they may also secure representation. As commonly understood, and with reference to their unique effectiveness as specimens, minerals are found only under favorable circumstances for crystallization (when not characteristically massive, amorphous, plastic, etc.) in cavities (pockets), veins, seams, or developed freely with crystallographic completeness in the interior of rock complexes.

Minerals practically are formed (1) in place, viz, their first and original position, in igneous, sedimentary and metamorphic rocks; (2) by crystallization from water or other solutions; (3) by deposition from fumes, vapors, etc.; (4) by the change, decomposition, alteration of older rocks; or minerals.

(1) Minerals of Sedimentary, Igneous and Metamorphic Rocks.

Among these three classes of rocks the Sedimentary, (the slates, sandstones and limestones), are the more poorly supplied with minerals, and indeed in a measure are destitute of them, as original contents. Modified by heat and pressure (metamorphism), infiltrated by water solutions, carrying mineral salts, secondary minerals are frequent in sedimentary rocks, but as original crystallizations they are not numerous. Perhaps a striking example is found in the occurrence of crystallized quartz in pellucid crystals in the calcareous sand-rocks of Herkimer Co., N. Y., though it is sensibly a later phenomenon than the laying down and consolidation of the rock they are found in. Again the gemmy sphalerite crystals that are found in the limestone at Tessin, Ohio, seem almost synchronous with the hardening of the matrix stone. Gypsum, anhydrite, occur in limestone beds, and their crystallization may have accompanied the hardening of the limestone beds themselves. The con-

RUTILE

Graves Mt., Lincoln Co., Ga.

Bement Collection, American Museum of Natural History

solidation of the sandstone in the region of the Bad Lands of Dakota represents a kind of cementation by calcareous material in which process siliceous calcites have been formed; crystals of calcite containing fifty to sixty per cent of quartz sand, like the Fontainebleau calcites, similarly constituted. In the Fort Pierre shale in S. Dakota, the internal cavities of the shale are often found to be studded with crystals of calcite. In carbonaceous shales or slates from Pennsylvania pyrite crystals are found well developed but these latter might be ascribed to metamorphic agencies. Sandstones contain frequently disseminated crystals of galena, pyrite, chalcopyrite, quartz, orthoclase, which may have formed within them as they finally assumed consolidation.

Igneous rocks are themselves crystalline aggregates and their constituent minerals are found often well formed, and individualized, in crevices, cavities, or imbedded in the rock as determinable units. In the volcanic blocks of Mt. Somma, Vesuvius, Italy, which have been ejected, Nephelite, Meionite, Chrysolite, Sarcolite, Wollastonite, Augite, mica (Meroxene), Humite, Clinohumite, Muromontite, Idocrase, Leucite, Haüynite, and other minerals are found well crystallized. The granitic syenites of Langesund Fiord, Norway, afford a wonderful gathering of rare minerals, and many, as gadolinite, wöhlerite, elaeolite, aegirite, sodalite, meliphanite, leucophanite, tritomite, either in crystals, massive, or in lamellar plates are taken out to enrich cabinets. Granites in their coarser and individualized condition yield beautiful minerals, crystallized in the quartz, mica, or feldspar of the granite, as beryls, garnets, tourmalines, topazes, allanite, with large and handsome specimens, in crystallized perfection, of quartz, mica, and feldspar; while the granite may also yield fluorite, apatite, cassiterite, magnetite, corundum, iolite, columbite and related minerals, chrysoberyl, xenotime, monazite, herderite, beryllonite, etc., and, as in the case of the Branchville, Fairfield Co., Conn., finds, yield nests of unusual phosphates (fairfieldite, dickinsonite, reddingite, eosphorite, triploidite, fillowite, lithiophyllite, etc.).

In the Archaean areas of New York, and elsewhere, very old volcanics yield interesting series of minerals as the pyroxenes, the segregated beds of magnetite, garnet, feldspars; labradorite in the north; while pegmatite veins, lenses, and masses form storehouses of unusual minerals throughout the world.

Metamorphic rocks are equally prolific in minerals, and the very process of metamorphism produces them. Here are included the metamorphic schists and their contents, and the baked limestones. Cyanite, fibrolite, mica, zoisite, hornblende, tourmaline, gar-

net, epidote, staurolite, andalusite, tremolite, glaucophane, actinolite, serpentine, pyrophyllite, axinite, spinel, chlorite, talc, are minerals that form schists or are associated with them, while sulphides (pyrite, chalcopyrite, sphalerite, molybdenite, bornite, galena), are often distributed in the metamorphic rocks, with oxides and other minerals (magnetite, chromite, hematite, chrysoberyl, ilmenite, rutile, cassiterite, diaspore, brucite, lazulite, titanite, topaz, apatite, fluorite, beryl, phenacite, euclase). In all these occurrences of minerals in rocks the collector is in search of good specimens, crystallized groups or individuals, on which the faces of crystals are recognizable, or else characteristic massive and partial phases.

Limestones which have been subjected to great heat, pressure, and metamorphosing agencies develop many minerals as tourmaline, garnet, pyroxene, vesuvianite, scapolite, (*wernerite*), quartz, zircon, danburite, spinel, corundum, chondrodite.

These are often found in the limestones, as a less dense or hard matrix, in beautiful perfection.

The traps (*dolerites*) furnish wonderfully beautiful crystallization of hydrous silicates, prehnite, apophyllite, natrolite, scolecite, chabazite, heulandite, gmelinite, stilbite, epistilbite, thomsonite, analcite and with them calcite in great variety of forms—as produced in successive "generations." These trap minerals have been formed as resultant compound silicate salts, containing water, from the decomposition of the trap itself. This decomposition has doubtless been assisted by the action of included steam or hot water, and, in a measure also, by telluric or surface waters which enter the trap from above. On this view many of them are to be referred to periods long antedating the present. The cold water percolating through the trap has a dissolving power, and Dr. Levison is inclined to refer all of these minerals as contemporaneous results to cold-water action. Mr. Fenner, in a paper of much interest, in which he summarizes his studies at Paterson, N. J., seems more disposed to advocate thermal agencies.

(2) By Crystallization from Water or Other Solutions.

Here belong the great number of deposited crystallizations found in veins or pockets, and which have resulted from crystals forming in saturated or slowly cooling solutions. Mine veins are a capital example, in which, whether by the rise of heated waters the lateral flow of wall waters or the descent of surface waters, crystals of metallic compounds have been formed. It may also happen that these crystallizations result from reactions between menstrua carrying varying salts, as when (theoretically) ironoxide bearing

waters from the surface met ascending waters, carrying copper salts, and metallic copper was precipitated, in the Michigan, Lake Superior, district. Again, crystals of common salt (halite), of gypsum, of sylvite, carnallite, kieserite, tachhydrite are formed in evaporating saline basins, and crystallize out. Such also have been the origins of the borax and ulexite in the salt marshes of Nevada. Bechilite, a borate of calcium, has been found as an incrustation at the baths of the boric acid lagoons of Tuscany, similarly Hayesine in the hot springs of the Cordilleras of Coquimbo. Many soluble minerals solidify from water in clay beds.

Lime formations of calcite and aragonite are created by water, and the activity of water, possessed of unlimited solvent powers, which are increased by heat and pressure, penetrating the earth, obedient to gravity and influenced by capillary attraction, is responsible for the cementation of rocks with lime, iron and silica, and for the occurrence of minerals in the interstices, over the cleavage or joint planes, and in the pits crevices and pockets of rocks. Quartz crystals and the amorphous forms of quartz as jasper, agate, chalcedony, opal, have formed from water solutions, and the universality of silica makes its minerals among the most common.

Water soon becomes a more active agent of solution, through dissolved alkalies and dissolved carbonic anhydride, and this increased power of solution brings about new mineral results in the development of feldspar crystals, epidote crystals, danburite crystals, (at Russell, N. Y., there are cavities full of calcite and containing pyroxene, titanite, tourmaline, mica, quartz, pyrite with great danburite crystals which must be regarded as solution deposition), dioptase, (as in the druses in seams of limestone in the Kirghese Steppes), while in subterranean channels of drainage and percolation the galena and sphalerite crystals (sulphides of lead and zinc) of the Ozark region (Missouri-Arkansas) have been accumulated along with the most superb developments of calcite.

The question of the deposition in lodes and veins of mineral material, brought there by water currents, and the causes involved in its localization after "an immense volume of solution has passed undisturbed through a section of rock very large in comparison with that in which it is finally concentrated," has been discussed for many years by chemists and mineralogists. Mr. Eugene C. Sullivan has collated all of this information and advanced the results by his own investigations. These studies show that waters carrying salts, upon filtration through soils, or passage through decomposed or comminuted rock part with their contents, and so give rise in the multivarious circulation (ascending and descending) to cumu-

lative depositions—which may be ore bodies or separate crystallizations. Still in veins and rock passages there is a prevalent reason for deposit, through concentration of the mineral menstrua, and the successive dropping out of mineral salts no longer retained in the solute. Highly heated water becomes a solvent and is finally a concentrated *solution,* and if ascending, slowly cooling at the same time and mingling with other solutions, gradually rids itself of its burden of mineral material in variously arranged deposits.

(3) By Deposition from Fumes, Vapors, etc.

A very well known illustration is the scale growth of hematite in good crystals at Etna and Vesuvius. The fumaroles of volcanoes contain in their exhalations, besides steam, fumes or vapors of hydrochloric, sulphurous, carbonic acids, and sulphuretted hydrogen. Reaction between these precipitate very often sulphur. Products of sublimation occur around volcanoes, as halite, sal-ammoniac, molysite (ferric chloride), while by the action of the hydrochloric acid upon the neighboring rock other chlorides are formed as chloride of calcium, of lead, of copper, of cobalt, of nickel. Similarly, sulphates might arise from the action of the sulphur acids, as sulphate of calcium, of sodium, of aluminium. In a secondary way the decomposition of the iron chloride by vapors of water (steam) would give rise to iron sesquioxide (hematite), while the volcanic carbonic anhydride would form carbonates. A still more profound process of mineral generation arises from the action of volcanic gases upon silicates whereby new compounds issue, and this action designated by Bunsen as *pneumatolysis* has been prolific of results in the interior of the earth's crust. The rhyolite, for instance, of the Thomas Mts., Utah, has been affected by mineralizing vapors, that have caused the development of topaz crystals with garnet and hematite.

(4) By the Change, Decomposition, Alteration of Older Rocks, or Minerals.

One aspect of Mineral generation would dwell upon primary and secondary minerals. The latter constitute a long and varied series and have been extensively formed from the decomposition of volcanic rocks. Here particularly belong the great group of *zeolites,* which in the trap of Iceland, Nova Scotia and New Jersey and India, are developed in unique beauty. They occur in seams and cavities, frequently preceded by incrustations of quartz, and the trap enclosing them is generally dark green, soft, and unctuous.

MANGANITE
Ilefeld, Harz Mts., Germany
Bement Collection, American Museum of Natural History

Parasite, from Montana, an unusual carbonate of rare bases (*cerium, lanthanum, didymium*), occurs in a fine-grained, loosely coherent white material, which seems to be a *decomposed* rhyolite or trachyte. A very common result of alteration is a change of one mineral into a derivative mineral, as when the sulphides of basic metals become oxydized and carbonated. In this way at the outcropping of veins of sulphides the copper sulphide is replaced by *malachite,* and *azurite,* and *cuprite,* and possibly copper sulphate (*chalcanthite, brochantite*), the lead sulphide (*galena*), becomes the sulphate (*anglesite*), the carbonate (*cerussite*), with rarely traces of *minium;* the iron sulphide, iron oxides, (*limonite*) iron carbonate (*siderite*) ; the zinc sulphide becomes zinc carbonate (*smithsonite*), the sulphate (*goslarite*) ; while *smaltite* (an arsenide of cobalt) becomes the red *erythrite* (an arsenate), while from the more composite phases of the mineral tetrahedrite (essentially a sulpharsenide or sulph-antimonide of copper with admixtures of other bases), malachite, azurite, bournonite, erythrite, cinnabar, covellite, amalgam, chalcopyrite, may result. The alteration of the andesitic and rhyolitic rocks at Goldfield has assisted in removing their lime and magnesia, most of their soda and potash, while water and sulphuric acid has been added, the solutions depositing ores being acid, possibly hot, and carrying gold, copper, bismuth, antimony, arsenic, selenium, tellurium. The gem mineral benitoite and its associate neptunite, occurring in the natrolite of a schist, in Benito Co., California, seem to have resulted from alteration, possibly combined with infiltration, and baking. In the midst of a large mass of serpentine, in the summit region north of Coalinga, Cal., patches of various kinds of schist occur, and in a section of these enclosed in the serpentine the Benitoite is found.

Collecting Specimens

Pits, excavations, quarries, cuts, are naturally localities where minerals may be expected, and minerals found at some depth are apt to be in a purer and firmer condition than those nearer the surface. Trimming specimens with square faced hammers improves their appearance. Working off extraneous or associated rock results in an enormous improvement, and the faces of crystals that are just seen may be developed into perfect or complete crystals. In this way idocrase crystals have been dug out of limestone, and neptunite crystals, that were entirely hidden, uncovered in a matrix of hard natrolite. Granite veins, metamorphosed limestones, contacts of invading igneous rock with the country rock, altered trap rocks, evaporated marine basins, igneous rocks generally, schists, form inviting and fruitful areas for examination. Metalliferous bodies in ore masses or in veins, yield attractive specimens and furnish scientific data of interest in speculations upon the genesis of minerals.

NOMENCLATURE.

The visitor to collections may be struck by the somewhat monotonous repetition of the termination *ite* upon the mineral labels. A word in regard to this uniformity may be welcome. This termination is derived from *itis*, meaning in the Greek, as a regular suffix, *of the nature of,* and this additive was used in this sense by the Greeks, afterwards by the Romans, and is now a part of modern usage.

The following paragraph from Dana exemplifies its employment and meaning: "*Haematites,* from the red color of the powder; *Chlorites,* from the green color; *Steatites,* from the greasy feel; *Dendritis,* from a resemblance to a tree or branch; *Alabastritis,* for the stone out of which a vase called an alabastron was made; *Basanites,* from the word for touchstone; *Siderites,* from the word for iron; *Argyritis,* from the Greek for silver; *Syenitis,* from the locality Syene, in Egypt; *Memphitis,* for a marble from Memphis, in Egypt."

Thus it has attached itself as a uniform termination to minerals, whether their names have been derived from proper nouns or from adjectives. The few exceptions to this practice have arisen from the well established and classic reputation and vogue of certain names, as epidote, tourmaline, quartz, cinnabar, serpentine, gypsum, etc.

In the classification of minerals the affinities between them, indicated by their chemical constitution, has afforded the most practical and natural means of arrangement, and it has been recognized that, generally speaking, chemical composition underlies the physical properties of minerals.

CLASSIFICATION.

The arrangement of the minerals in museum cabinets adheres closely to the broad divisions used by Professor Dana in his "System of Mineralogy," beginning with the native elements, followed by their compounds, which are again separated into a series of sections the members of which present general similarities of chemical constitution.   The general classification then assumes this form:

I. Native Elements.
II. Sulphides, Selenides, Tellurides, Arsenides, Antimonides.
III. Sulpho-salts, Sulpharsenites, Sulphantimonites, Sulpho-bismuthites.
IV. Haloids, Chlorides, Bromides, Iodides, Fluorides.
V. Oxides.
VI. Oxygen Salts, or compounds formed of bases and acids which embrace: 1. *Silicates.* 2. *Columbates, Tantalates.* 3. *Phosphates, Arsenates, Antimonates, Nitrates.* 4. *Borates.* 5. *Tungstates, Molybates, Vanadates.* 6. *Sulphates, Chromates, Tellurates.* 7. *Carbonates.* 8. *Oxalates, Mellates.*
VII. Hydrocarbon Compounds.

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The visitor to cabinets by whom Mineralogy has not been studied, or possibly even thought of, and in whom an inspection of the collection awakens any desire to become better acquainted with its character and extent, will find the following works useful to him in his studies:

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(The above works are published by Jno. Wiley & Sons, of this city, whose assistance in the illustration of this GUIDE is gratefully acknowledged).

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THE NATIVE ELEMENTS.

Owing to the early activity of chemical agencies and the still continuing energy of oxygen, a gas which is constantly attacking the uncombined elements and changing them to oxides, the list of native elements upon or in the earth, as we at present know them is much shorter than the list known to chemistry (p. 89), while a large number of elements are precluded from any independent existence whatever by their strong affinities. Thus, fluorine, until lately, unknown even in the laboratory in a free state, instantly combines with water, forming hydrofluoric acid, and in this form it rapidly attacks silica and disappears into numerous other combinations. Similarly bromide, iodine and chlorine cannot long remain uncombined, and their separation from their compounds with negative bases is to-day a chemical and artificial process, except in some rare occurrences connected with volcanic phenomena. It may be possible that in the interior regions of the earth, where high temperatures prevail, many of the elements exist uncombined, and reactions may there take place which frequently liberate the elements from their natural combinations. The mineralogist finds, however, within or upon the earth surfaces examined by him, a small list of native elements, of which six at the most are characteristically uncombined, while the remainder, about fifteen, are found native exceptionally, while one of these, iron, maintains its frequency and essential interest from coming to the earth from extra-terrestrial sources, viz, in meteoric showers.

Mineral collections contain the following native elements, grouped according to the chemical divisions given above into non-metallic, semi-metallic and metallic species, viz, *Sulphur, Graphite,* Selensulphur; Antimony, Bismuth, Tellurium, Arsenic, Allemontite, Gold, Silver, Copper, Mercury, Amalgam (silver and mercury, a
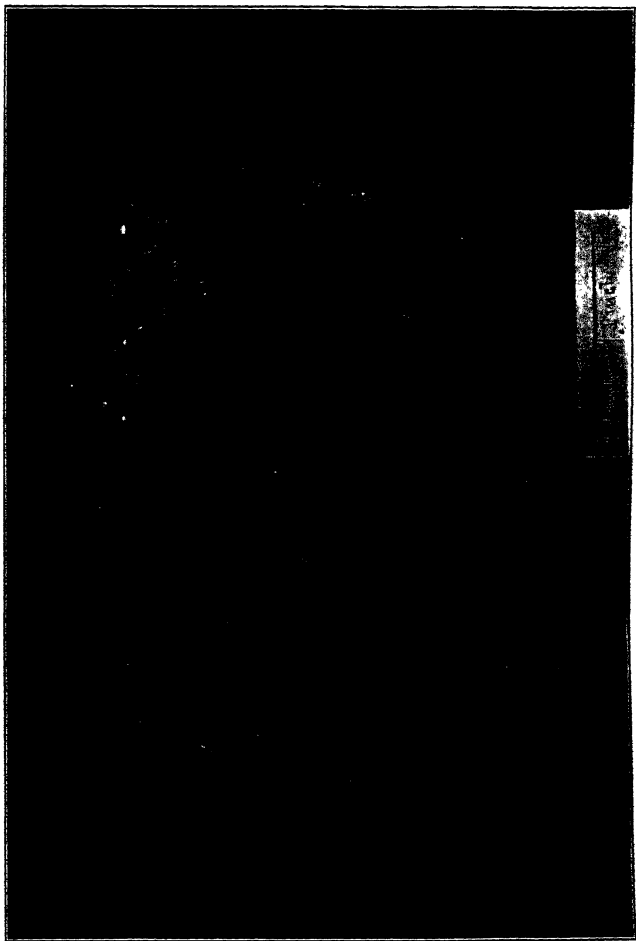
LIMONITE (pseudomorph after Siderite)
Pike's Peak, Col.

Bement Collection, American Museum of Natural History

natural alloy), Platinum, Platiniridium, Iridosmine; and Iron, which last is almost entirely limited to meteoric falls.

Of these, gold, platinum, platiniridium and iridosminum alone resist combination with the other elements, so that their charac-teristic appearance in the rocks of the earth is confined to a native or uncombined condition, while the commercial value of the first and its intrinsic beauty when crystallized, make it the most attrac-tive of the native metals.

Gold crystallizes in the isometric system and usually in octa-
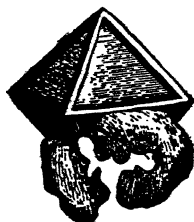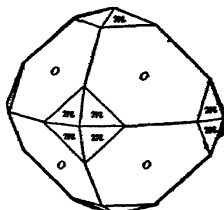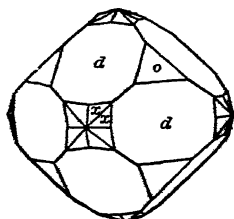
Fig. 296   Fig. 297   Fig. 298
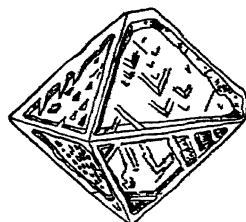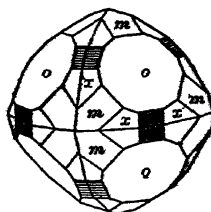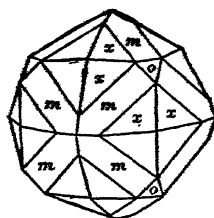
Fig. 300   Fig. 301   Fig. 302

PLATE 13

hedrons and rhombic dodecahedrons. Plate 13 shows some of its more frequent shapes, with cavernous and pitted faces, in Figs. 296 and 302. It also assumes deceptively the appearance of hexa-gonal prisms, as pointed out by Prof. Wm. P. Blake in gold from Sonora, Tuolumne County, California, which suggestively recall the prismatic forms obtained by digesting gold amalgam. (Le Sage, 1777; Chester, 1878).

Gold from an elongated octahedron assumes rhombohedral forms, while cavernous, skeleton and pitted crystals, peculiar dis-

tortions, reticulated and lace-shaped groups with spongy masses, lath-shaped ribbons, mosslike veils, etc., or rounded water-worn nuggets, are common natural appearances of this precious metal, and may be seen in the specimens exhibited in any cabinet of considerable size. There often appears amongst the golds interesting examples of filiform gold in the hollow faces of amethyst crystals and elongated octahedrons sprinkled over quartz from Hungary; gold in pyrite on chert from Colorado; circular and irregular deposits on gneiss from the Tyrol; the variety Electrum containing silver, and Porpezite containing palladium, and plates or scales of gold upon and through quartz.

Gold will often be noted in sheets like rolled out metal, in plates with crystallized edges, in braided like filaments made up of minute octahedrons, grouped octahedrons with hollow faces, in twisted plates frequently attached to quartz, around which it is developed like some irregular flower. The plates are produced faces of octahedrons, sometimes with beads of gold along their edges. In many cases the gold is in plates closely appressed, presenting a fluted appearance. There are often elongated octahedrons or rhombic dodecahedrons. Amongst localities Transylvania, California, Oregon, Australia and Brazil will be of common occurrence. Gold as shown by Prof. E. S. Dana is often elongated into forms resembling rhombohedrons, which are really produced faces of a tetragonal trisoctahedron.

Gold occurs in place for the most part in quartz veins, which intersect chloritic, slaty and talcose rocks; more rarely in schists and gneiss (Brazil). The disintegration and weathering of the rock dislodge fragments which falling away become more reduced in size until finally their contained gold is disseminated through a mass of sand or gravel. The washing of water carries this material into hollows or river channels and the gold films separated by their equal gravity sink and become included in an associated matrix of rubble and clay.

These form the *placer* deposits, while the finer gold (float gold) in a dust is carried still further and more widely distributed. Gold has been brought into the quartz veins, probably, by highly heated water action from the surrounding rock, and its presence in cavities in calcite (carbonate of lime) crystals and through quartz crystals, prove its aqueous origin. In no instance, probably, has it been brought where it is found by igneous action.

Professor Wurtz has suggested that iron salts dissolved the gold, and concentrated it in solution in vein crevices where it was again deposited. The very common association of gold with pyrite (iron sulphides) point to some casual connection between the two min-

erals. Recently it has been strongly urged that gold has been deposited from solution by electrical currents, and the chloride of gold, a well known salt of gold and present in sea water, has been suggested as its source, and ground or earth currents invoked as the precipitating agency, also as a solvent, iodides and bromides in the sea water have been suggested.

Alluvial washings have contributed the largest part of the gold product of the world, and California, Australia, Brazil and the Ural Mountains are the most important producers. Lately the gold mines of South Africa have contested their claim to pre-eminence, especially those in the Kaap gold fields in southeastern Transvaal.

In 1890 the United States produced $32,845,000.
In 1890 Australasia produced $30,416,000.
In 1890 Russia produced $21,161,700.
In 1890 Africa produced $9,887,000.
In 1900 the United States produced $78,160,000.
In 1901 the United States produced $82,750,000.
In 1902 the United States produced $80,000,000.
In 1903 the United States produced $73,591,700.
In 1904 the United States produced $80,464,700.
In 1905 the United States produced $88,180,700.
In 1906 the United States produced $94,373,800.
In 1907 the United States produced $90,500,000.
In 1908 the United States produced $94,500,000.
In 1909 the United States produced $99,673,400.

The California gold is about 89 per cent fine and the purest gold described is that from Mt. Morgan in Queensland, which has yielded 99.7 to 99.8 of gold, with only a slight amount of copper and iron.

Gold is twinned according to the spinel law, viz, two octahedrons, turned, half way round (*hemitrope*) are united on an octahedral face. This twin may be repeated, producing complex groupings.

Although inert usually with short exposures to most reagents, the opinion now gains ground that with long exposure to their action gold is acted upon by bromides, iodides, nitrate of ammonia, nitric acid; while sulphuretted hydrogen precipitates gold as a sulphide, in gold solutions, which again acted on by alkaline sulphides yields a double sulphide. Telluride of gold exposed to a current of hydrogen is reduced to a wire form, and hydrogen exercising such reducing power has been invoked to explain the occurrence of filiform gold. Again Cumenge has shown that alkaline aurates in a solution of soda silicate give a stable aurosilicate decomposed

under the action of hydrochloric or carbonic acids, yielding a gelatinous silica holding gold. Gold solutions are precipitated by metallic sulphides as pyrite, sphalerite, galena, chalcopyrite, mispickel, molybdenite, argentite, and the gold precipitated is brilliant and coherent. The metals and reducing acids, as sulphurous, phosphorous, arsenious; copper chloride, ferrous salts, tin protochloride and organic substances all precipitate gold, and many such reactions may have been involved in bringing gold into many minerals.

Gold nuggets have been found of remarkable size. In Australia 95 kilogrammes was the weight of a single mass; the gold crystallizations are frequently worn or rounded, but, distended into arborescent sheets, form beautiful objects. Eldorado, Cal.; Breckenridge, Colorado, have produced very handsome specimens and in the pay-dirt, against the rock flooring, in Alaska, numerous rolled nuggets occur. Gold, besides such more usual placements, already mentioned, has been found in granite, porphyries, liparites, rhyolite, trachytes, andesites, phonolite, diorites, diabases, basalt, serpentine, gneiss, schists, conglomerates, (Black Hills, Witwatersand), limestone. Associated with gold is a long list of minerals, many rare and gem-like. They consist of the diamond, ruby, sapphire, beryl, phenacite, euclase, zircon, amethyst, chrysolite, garnet, cyanite, rutile, anatase, brookite, tourmaline, topaz, xenotime, monazite, samarskite, columbite, fergusonite, allanite, thorite, platinum, platiniridium, magnetite, chromite, hematite. Gold is widely disseminated in minerals and has been extracted from feldspars, micas, chlorite, amphiboles, garnets, epidote, chrysotile, titanite, tourmaline, allanite, prehnite, chrysocolla, rhodonite, realgar, orpiment, stibnite, molybdenite, pyrite, alabandite, pyrrhotite, chalcopyrite, chalcocite, covellite, sphalerite, galena, bismuthinite, cinnabar, argentite, mispickel, enargite, tennantite, meneghinite, jamesonite, bournonite, freieslebenite, proustite, pyrargyrite, stephanite, polybasite, altaite, tetradymite, coloradoite, almost all the tellurides, cerargyrite, embolite, iodyrite, fluorite, uraninite, magnetite, hematite, ilmenite, cassiterite, calcite, dolomite, siderite, barite, gypsum, apatite, wulfenite, vanadinite, crocoite, scheelite, wolframite, stolzite, polycrasite, diamond (a diamond from Kimberley enclosed two grains of gold), sulphur, arsenic, antimony, tellurium, bismuth. Nuggets of gold have been considered as accretions made up of successive layers of deposit, although they show when polished and etched crystalline structure.

Silver, like gold, crystallizes in the isometric system, but is usually found in threads, wires, or elongated crystals, these latter groups forming branching arms or arrow-pointed blades, produced by crystals sprouting in directions parallel to the diagonals of an

BRUCITE
Texas, Pa.
Bement Collection, American Museum of Natural History

octahedral face, while in massive condition it is found in plates, scales and nodules. Some attractive specimens are to be seen in collections illustrating these conditions, and in many mineral cabinets the metal is seen in limestone penetrating the rock in twisted and curved filaments, together with arborescent and encrusting forms.

Some of the most beautiful silver specimens are found in association with the native copper of Lake Superior, where it occurs in grains, plates and crystals, having been deposited in conjunction with the copper matrix in which it is now embedded. Mexico and Peru have produced the most silver, and in Peru especially native silver abounds. In Peru a silver mass has been found which weighed over eight hundred pounds, and one from Batopilas weighed when obtained four hundred pounds.

Some light has been thrown recently upon the origin of such extraordinary masses and, as in the case of gold, electric ground currents, as well as chemical or metallic deposition, as when from a silver salt in solution, metallic silver is precipitated by copper plates, have been suggested as the actual agencies which have concentrated silver in these native nuggets (see Copper). Silver is found in veins traversing schists, porphyry and gneiss; while, as examples in the cases show, it lies intricately crystallized in limestone beds.

The enclosed extract, from David T. Day's Report on the Mineral Resources of the United States, as to the comparative production of gold and silver for the last forty years is of interest in this connection:

"A study of the world's annual production of gold and silver, and the price of silver from 1850 to 1889, shows that the world's gold production from 1850 to 1857 remained nearly constant at about $134,000,000; then decreased irregularly till 1883, reaching a minimum of $97,000,000; then increased irregularly to 1889, when the product was $120,000,000. The silver production remained nearly constant from 1850 to 1860 at above $40,000,000, increasing slowly to 1866 to $52,000,000; then increased steadily and rapidly to 1887, and still more rapidly in 1888 and 1889 to $159,000,000."

The demonetization of silver has, since 1890, greatly increased the world's output of gold. New gold deposits (Australia, South Africa, Colorado) have been opened and more rigor exerted in mining and development. In collections remarkable silvers from Kongsberg, Norway, will be noticed. It will be seen in octahedrons, also in cubes and rhombic dodecahedrons, in form of wire

silver, entangled threads like moss, beautiful examples of crystallized silver looking like trees, being lines of silver with branching arms and secondary branches. These latter, finely reticulating, may be from Sardinia or Mexico.

Again, silver masses occur rounded and blistered, as if melted. These occur in calcite from Kongsberg. In rare examples flattened rhombic dodecahedrons occur. The silver from Lake Superior is associated with copper, and yet, although thus imbedded, unalloyed with its host. From the copper regions of Lake Superior there is often seen exquisite natural metal aigrettes or brooches made up of silver crystals and wires taken out of calcite, that has been removed by acid.

The silver production of the United States for 1909 was $28,455,200.

The extraordinary wedges or·"leads" of native silver in the Cobalt, Ontario, region of Canada, are difficult to account for. Silver is reduced from its sulphide and antimonide and it is also precipitated from its solution by pyrite, chalcopyrite, galena, and other sulphides. Reactions, perhaps similar to these, accumulated in beds, (afterwards inverted), these silver masses.

The visitor to a representative collection, after the specimens of gold and silver, will be most attracted by the beautiful crystallizations of **Copper.** These specimens generally come from the remarkable deposits of native copper in the Lake Superior region of northern Michigan. They exhibit the characteristic crystallizations of the mineral (isometric system),· the entrained sprigs and branches of crystals, twins and massive plates, the common tetrahexahedrons (Figs. 305-309) cubes and superimposed octahedrons (Figs. 303-316), and amongst them examples of the associated copper and silver alluded to above.

Fig. 303   Fig. 304
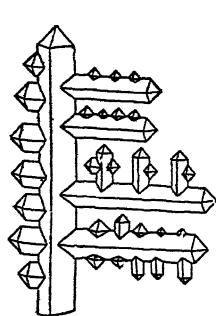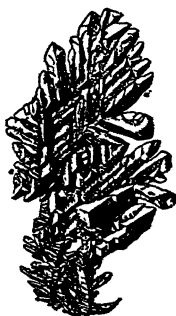
The copper deposits of the Keweenaw Point, Portage Lake, and Ontonagon River districts in north Michigan, are located in a region which combines two contrasted series of rocks; conglomerates, sandstones, as a series originating in water, as a shore deposit; and igneous intruded rocks which have welled up from some internal source of melted or fused mineral matter and penetrated
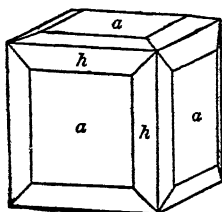
Fig. 305
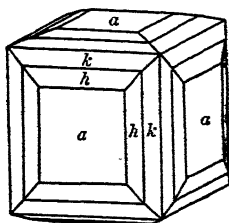
Fig. 306
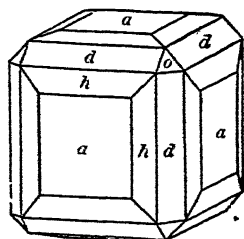
Fig. 3?7
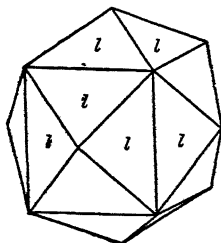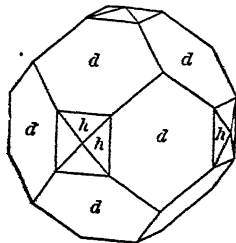
Fig. 308

Fig. 309
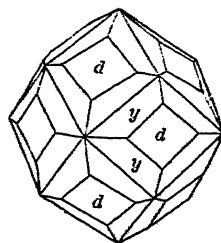
Fig. 310
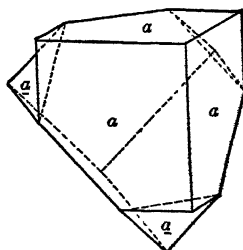
Fig. 311
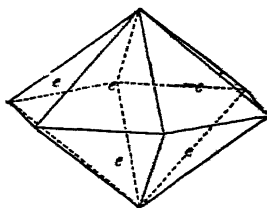
Fig. 312
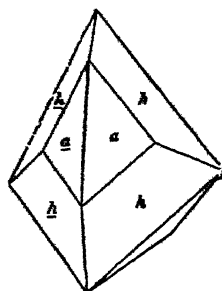
Fig 313
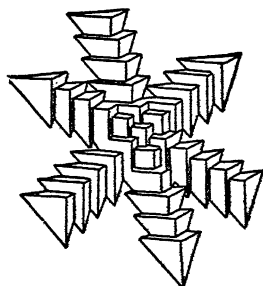
Fig. 314

Fig. 315

Fig. 316

PLATE 14

the sandstone or, according to Irving and Chamberlain, have formed sheets between successive beds of these coarse, sandy and pebbly conglomerates.

From this latter view we derive the impression of a period of volcanic activity, succeeded by a period of rest during which the conglomerates and sandstones were deposited, which again was followed by renewed ejections of doleritic or igneous matter in their turn to be sealed in by later shore or shoal water beds of sandstone.

At the contact between these contrasted beds and developed through them the copper is found in strings, sheets, crystals and masses. The theory which most adequately accounts for this remarkable development is, comprehensively stated, this: the slowly rising columns of igneous rock have brought with them from deeply seated areas or entrapped in their flow through the earth's crust, a great volume of copper salts; these in a heated state have met surface waters carrying perhaps iron oxides, a reaction has been commenced and has been carried out, gradually precipitating the copper contents of the rocks through all the interstices, crevices and openings, wherein the two menstrua met. It is essentially a water action, and the detection of copper surrounded by calcite crystals, and the presence of silver in the midst of the copper, unalloyed with its enclosing matrix, prove that both have slowly, molecule by molecule, been chemically deposited from solutions.

The largest single mass of native copper found in this region was discovered in 1857; it was 45 feet long, 22 feet at the widest part, and 8 feet thick; it weighed 420 tons. The copper production from other sources has reduced the percentage of Lake Superior copper in the total product, so that whereas in 1869, 95 per cent of the total product came from Lake Superior, in 1890 it had fallen to 39 per cent. In 1900 the United States produced 601,-000,000 pounds of copper.

Prof. E. S. Dana has remarked the irregularities of the simple forms of native copper and has pointed out its resemblance to gold "in the frequency with which its crystals show hollow and cavernous forms." Dodecahedrons show cavities, while sometimes, where the forms are hardly more than skeletons, the crystal "although nearly perfect is in fact a mere shell." Elevations triangular, four or six-sided, also appear over the crystalline faces and the most unexpected combinations occur with a prevailing "tendency of the crystals to develop rhombohedral symmetry."

CALCITE
Harz Mts., Germany
Bement Collection, American Museum of Natural Hist
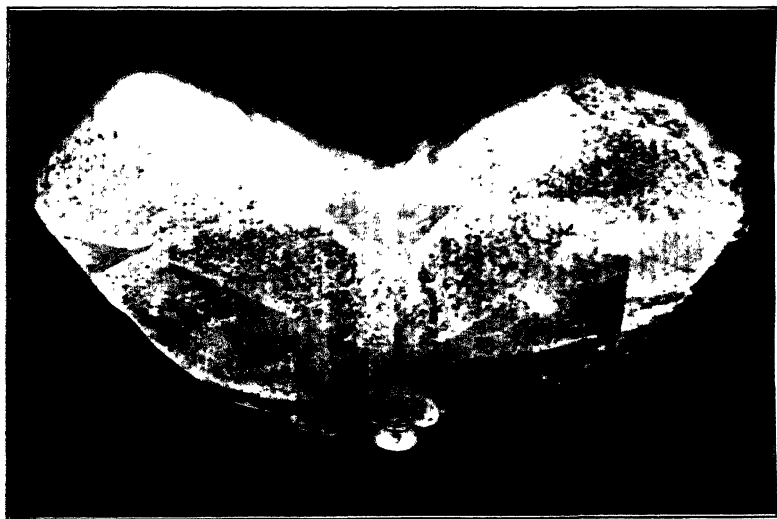
CALCITE (Twinned)
Egremont, Cumberland, Eng.
Bement Collection, American Museum of Natural History

Throughout the copper specimens examples of twinning will be common (Figs. 311-313); cubes, octahedrons and hexoctahedrons, the latter with half their faces omitted looking like six-sided low pyramids; again, stout columns of crystals. There may be often seen interesting lines of cubes, with faint hexoctahedral faces, also many specimens, as in the case of silver, arborescent, branching out regularly from a middle stem, and these branches again sprouting secondary branches, an identity of habit arising from identity of crystallization. Here are pseudomorphs from Corro-Corro, S. A., in six-sided prisms after twinned aragonite, their sides inclined inward, the whole form looking rudely like a toy capstan.

Notable and particularly beautiful specimens of crystallized Native Copper have been found at Bisbee, Arizona, where, implanted on a limonitic base, they were developed into thickets of naillike elongated prismatic crystals, possibly tetrahexahedrons, with minutely dentate edges, of brilliant surface and associated with thickly clustered individual crystals. The specimens are not large but their effectiveness as mineral developments is remarkable.

The production of Copper in the United States for 1906 was 917,805,682 pounds, the world's production was 1,596,973,700. In 1908 the production of Copper in the United States was 943,000,000 pounds, valued at $124,500,000, in 1909 its value was $142,083,711.

The native Iron in cabinets is usually entirely meteoric, that is, it has fallen from space upon the surface of the earth. There is found upon the earth iron which has been formed in place, reduced, generally in the vicinity or amidst igneous rock, by heated carbonaceous substances or vapors. The Ovifak iron of Greenland is a famous example of terrestrial iron. The meteoric irons contain almost universally nickel which, according to its amount in the iron, forms three separate combinations known as *Plessite, Taenite, Kamacite,* and these irregular mixtures are instrumental in giving rise to the so-called *Widmanstätten figures,* which are the edges of nickelferous iron usually parallel to the octahedral faces and developed by etching the iron with dilute nitric acid. The meteorites are broadly divided into two classes, the *Aerolites* or stony masses, made up for the most part of silicates, and the *Siderites* or true iron masses, almost entirely composed of iron enclosing olivine (chrysolite) and troilite (sulphide of iron) with other rare mineral compounds. A less extensive and third class is the *Siderolites,* a group between the former two; in which stony or mineral material is admixed or enclosed in iron—the metallic and stony constituents of the mass being represented in almost equal volume. The elements represented in Meteorites number about twenty-three, and are, in alphabetical order, as follows:

Aluminium
Antimony
Arsenic
Calcium
Carbon
Chlorine
Chromium
Cobalt

Copper
Hydrogen
Iron
Lithium
Magnesium
Manganese
Nickel
Oxygen

Phosphorus
Potassium
Silicon
Sodium
Sulphur
Tin
Titanium

Minerals supposed to be peculiar to meteorites are *Cliftonite,* a form of graphitic carbon: *Cohenite,* a combination of carbon with iron, nickel and cobalt: *Schreibersite,* the union of phosphorus with iron and nickel: *Troilite,* a sulphide of iron; *Daubreelite,* a sulphide of iron and chromium; and *Lawrencite,* the chloride of iron.

Two minerals of terrestrial origin containing iron and nickel are *Josephinite* of Oregon, and *Awaruite* of New Zealand, both as rolled stream-worn nuggets.

Amongst the remaining native metallic elements the cabinet may possess specimens of platinum, platiniridium, iridosmium, mercury, amalgam and lead.

Platinum is largely derived from two districts in Russia, the Isa and Demidoff, consisting of dried but recent river-beds, where in placer deposits the scales and rolled nuggets of platinum are gathered from the washed gravels and sand.

By reason of the enhanced value of platinum—rising in 1907 to $41 per ounce—renewed efforts to increase its production have been made. Perhaps 23,292 pounds of this rare metal are required yearly by the civilized world, of which the United States take 7,200 pounds. Colombia has entered the field of producers. It is found principally "on the divide between the heads of the Atrato and the San Juan Rivers in the Choco region," in a zone or layer of gravel, sand, stone, and various clays, parallel with the horizon and lying within very narrow limits. In the United States black shore and placer sands in California and Oregon have yielded platinum while Nevada and Utah show the occurrence of the metal in copper-nickel ores.

The name comes from *plata,* Spanish for silver, and the metal first came from South America.

In Russia **Platiniridium** and **Iridosmine** are obtained, though the latter occurs also in California, Australia and North Grenada.

Mercury and Amalgam (mercury and silver) are rare species, but the examples show the former scattered in globules over cinnabar and clay slate, while the latter may be shown as a silvery filling of narrow fissures, found in the Palatinate, where it is said

to occur "where the veins of mercury and silver intersect one another," also at Mariposa, Calif., and Rosenau, Hungary.

Lead is found in a native state quite extensively, though only in scales and grains. It has been reduced from its ores, and it has been suggested that arsenious acid effected this reduction. Specimens from Paisburg, Sweden, are in dolomite.

In reviewing the metallic elements a common system seems shown by their common crystallization in the isometric system, and this identity of crystalline system is reflected in the science elsewhere, where community of composition goes along with crystalline character.

The semi-metallic elements, sulphur and graphite, close the series of native elements. Of these the sulphur specimens are conspicuous for their beautiful crystallization and fine color. Most of the specimens come from Girgenti, Sicily, and some very pretty tapering encrustations are sometimes exhibited from the fumeroles of the Sandwich Islands.
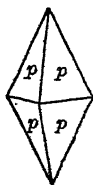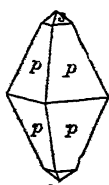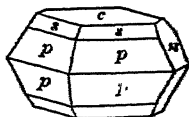
Fig. 317   Fig. 318   Fig. 319   Fig. 320   Fig. 321

Fig. 322   Fig. 323

PLATE 15
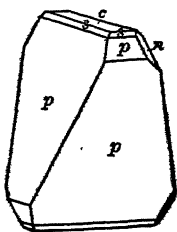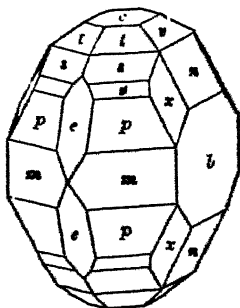
Sulphur crystallizes in the orthorhombic system, and the crystals from Sicily in the cabinet illustrate the orthorhombic habit of the mineral. They are made of pyramids of different inclinations and of domes. Occasionally so-called hemihedrism is displayed giving sphenoidal forms (Figs. 317-323). The sulphur deposits of the earth are found in connection with gypsum beds or active and extinct volcanoes. The sulphur has been produced by separation from sulphuretted hydrogen which in burning or oxidation gives rise to a deposit of sulphur, and the sulphuretted hydrogen has in turn come from the decomposition of vegetable and animal organisms. Sulphur is found in large deposits in Wyoming, Nevada, Southern Utah, and California.

An examination of the sulphur crystals will generally reveal upon the large, perfectly formed crystals curiously wrinkled surfaces. The crystals present brilliant surfaces, the crystals are frequently clear and translucent, their crystallographic habit is steep pyramids with narrow filletlike faces of more obtuse pyramids, and frequently sphenoids(?) very generally broad basal pinacoids, also prisms and domes and hemi-pyramids. Crystals occur sometimes darkened with bituminous matter; faces may often have clouded or ground glass surfaces, which under the glass reveal a finely pitted surface and wavelike oblique lines; also more roughened surfaces with deeper, densely crowded pits; occasionally a rim about the face edge with the face itself depressed. In selensulphur, where there is an admixture of selenium, the color is darker.

Twinning in Sulphur is rare. The best crystals are found in marl or clay along with calcite, gypsum, celestite, aragonite (themselves, especially *gypsum*, frequently superbly developed) where the crystals seem to have been formed from hot waters. Girgenti, Sicily, has furnished admirable crystals. Sulphur is dimorphous, assuming monoclinic forms where fused and cooled.

In Louisiana beds, deeply seated, of Sulphur, have been extracted by a system of melting the buried sulphur, and pumping it to the surface. In 1909 the sulphur product of the United States was valued at $4,432,000.

Graphite is, with the exception of the diamond, the purest form of carbon, and its impurities are largely mechanical admixtures of iron or clay. It occurs in flakes, streaks, and nodules or masses in metamorphic rocks, where it seems to have been developed by heat and distillation from vegetable remains. The mines at Ticonderoga, N. Y., produced in 1890 about 400,000 pounds of refined graphite.
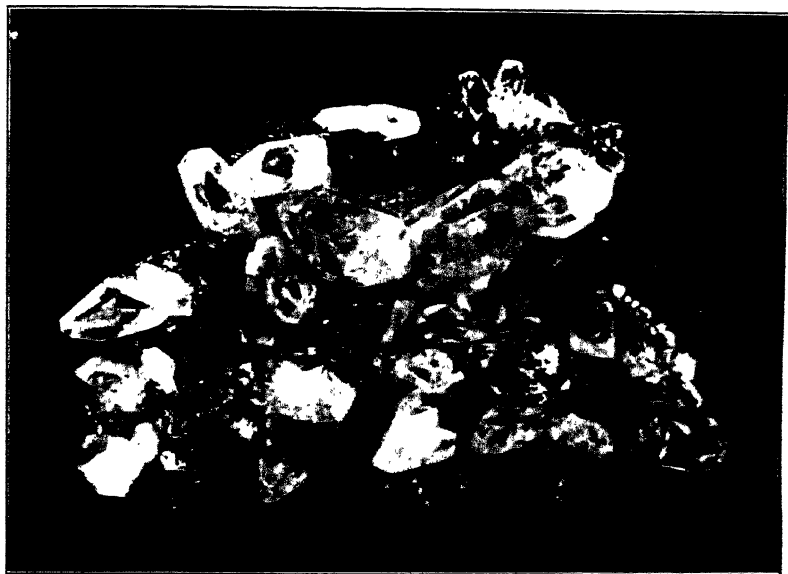
CALCITE
Cumberland, England
Bement Collection, American Museum of Natural History

CALCITE (Twins)
Egremont, England
Bement Collection, American Museum of Natural History

The value of imports of this mineral is over six times that of the graphite mined in this country. Pennsylvania comes first as a producer in the United States, New York second, Alabama third. In 1905 the United States produced 30,000,000 pounds, valued at $318,211. Ceylon and Austria are the greatest producers. The value of the graphite mined in the United States in 1909 was $345,000.

The **Diamond**, the most beautiful of gems, is a form of crystallized carbon. Its origin in nature is still a mystery, and it may be doubted whether its artificial production in the electric furnace by Moissan throws much light on the processes of its formation in the rocks of the earth. The most prominent and productive sources of this mineral are now located in S. Africa in the De Beers properties represented by the Kimberley, Wesselton and Bultfontein mines. In 1909 these mines probably produced some 1,860,000 karats, and the value of diamonds sold, and of stocks on hand, at cost of production was about $15,000,000. Besides the above mentioned mines the Transvaal, (*Premier mine*), Orange River (*Jagersfontein mine*), German S. W. Africa, have yielded diamonds. The enormous Cullinan diamond mass weighing over 3000 karats came from the Premier mine. The Minas Geraes province in Brazil continues to furnish diamonds, also British Guiana, and New South Wales.

The commercial production of diamonds has never been realized in the United States. At present some business prospects obtain in Arkansas where in *peridotite* outcrops some 1000 diamonds weighing about 500 karats (Sterrett) have been extracted. The Arkansas Diamond Co., the Ozark Diamond Mines Co., and the American Diamond Co., are the principal holders of these properties. "The igneous rock in which the diamonds are found is a vitreous peridotite, forming a stock or volcanic neck, which has broken up through the Carboniferous and cretaceous quartzites and sandstones. After an extensive period of erosion, during which an unknown portion of the neck and presumably a previously existent volcanic cone have been removed, the surface was covered with thin beds of Post-Tertiary conglomerate." Apparently there was not much change produced in the country-rock; the neck of peridotite is a vertical column and may extend downward indefinitely. The surface exposure is a rough ellipse 2400 feet in the long and 1800 feet in the shorter diameter.

Almost all public museum collections will contain crystals of diamonds with specimens of *bort* and black diamond.

(Consult special treatises as Max Bauer, Edelsteinkunde; I. F. Williams, Diamond Mines of South Africa; Goldschmitt, The Diamond).

The next group of minerals after leaving the Native Elements are the Sulphides, Selenides and Tellurides of the Semi-Metals, and the Sulphides, Selenides, Tellurides, Arsenides and Antimonides of the Metals, which is again succeeded by the so-called Sulpho-Salts, or combinations of sulphur with arsenic and antimony with metallic bases, where the unions of sulphur with arsenic and antimony are regarded as acids forming unions with bases, chiefly copper, silver, lead, iron, zinc, mercury. The great variety and number of mineral species resulting from the numerous combinations thus made possible, preclude any detailed reference to the less important species. The species in the different groups usually represented in cabinets are given in the following list, and the more important common and striking species particularly mentioned in the succeeding paragraphs.

SULPHIDES, SELENIDES, TELLURIDES OF THE SEMI-METALS

	System.	*Composition.*
Realgar.	Monoclinic.	Sulphide of arsenic.
Orpiment.	Orthorhombic.	Sulphide of arsenic.
Stibnite.	"	Sulphide of antimony.
Bismuthinite.	"	Sulphide of bismuth.
Tetradymite.	Hexagonal.	Telluride of bismuth.
Molybdenite.	"	Sulphide of molybdenum.

SULPHIDES, SELENIDES, TELLURIDES ARSENIDES, ANTIMONIDES OF THE METALS

Dyscrasite.	Orthorhombic.	Antimonide of silver.
Domeykite.	"	Arsenide of copper.
Chilenite.	"	Bismuthide of silver.

GALENA GROUP.

Species.	*System.*	*Composition.*
Argentite.	Isometric.	Sulphide of silver.
Hessite.	"	Telluride of silver.
Galenite.	"	Sulphide of lead.

Species.	*System.*	*Composition.*
Altaite.	Isometric.	Telluride of lead.
Clausthalite.	"	Selenide of lead.
Berzelianite.	"	Selenide of copper.
Lehrbachite.	"	Selenide of lead.
Zorgite.	"	Selenide of lead, copper, silver.
Chalcocite.	Orthorhombic.	Sulphide of copper.
Stromeyerite.	"	Sulphide of copper and silver.
Sternbergite.	"	Sulphide of silver and iron.
Acanthite.	"	Sulphide of silver.
Sphalerite.	Isometric.	Sulphide of zinc.
Metacinnabarite.	"	Sulphide of mercury.
Tiemannite.	"	Selenide of mercury.
Alabandite.	"	Sulphide of manganese.
Pentlandite.	"	Sulphide of iron and nickel.
Cinnabar.	Hexagonal.	Sulphide of mercury.
Greenockite.	"	Sulphide of cadmium
Wurtzite.	"	Sulphide of zinc.
Millerite.	"	Sulphide of nickel.
Niccolite.	"	Arsenide of nickel.
Breithauptite.	"	Antimonide of nickel.
Pyrrhotite.	"	Sulphide of iron.
Bornite.	Isometric.	Sulphide of copper and iron.
Linnaeite.	"	Sulphide of cobalt.
Cubanite.	"	Sulphide of iron.
Chalcopyrite.	Tetragonal.	Sulphide of copper and iron.
(Barnhardtite).		
Pyrite.	Isometric.	Sulphide of iron.
Hauerite.	"	Sulphide of manganese.
Smaltite.	"	Arsenide of cobalt.
(Chloanthite).		
Cobaltite.	"	Sulphide & arsenide of cobalt.
Gersdorffite.	".	Sulphide & arsenide of nickel.
Ullmannite.	"	Sulphide & antimonide of nickel.
Skutterudite.	"	Arsenide of cobalt.
Marcasite.	Orthorhombic.	Sulphide of iron.
Leucopyrite.	"	Arsenide of iron.
(Lollingite).		
Arsenopyrite.	"	Arsenide and sulphide of iron.

Species.	System.	Composition.
Rammelsbergite.	"	Arsenide of nickel.
Glaucodot.	"	Sulphide of cobalt and iron.
Alloclasite.	"	Sulphide of cobalt, iron, arsenic, [and bismuth.
Sylvanite.	Monoclinic.	Telluride of silver and gold.
Nagyagite.	Orthorhombic.	Gold, lead, antimony, tellurium, [and sulphur.
Kermesite.	Monoclinic.	Oxysulphide of antimony.

SULPHARSENITES, SULPHANTIMONIDES

Species.	System.	Composition.
Livingstonite.	Monoclinic.	Mercury, antimony, sulphur.
Zinkenite.	Orthorhombic.	Sulphide & antimonide of lead.
Sartorite.	"	Sulphide & arsenide of lead.
Emplectite.	"	Sulphide & bismuthinide of cop- [per.
Berthierite.	"	Sulphide & antimonide of iron.
Plagionite.	Monoclinic.	Sulphide & antimonide of lead.
Binnite.	Isometric.	Sulphide & arsenide of copper.
Dufrenoysite.	Orthorhombic.	Sulphide & arsenide of lead.
Jamesonite.	"	Sulphide & antimonide of lead.
Freieslebenite.	Monoclinic.	Sulphide & antimonide of lead [and silver.
Bournonite.	Orthorhombic.	Sulphide and antimonide of cop- [per and lead.
Aikinite.	"	Sulphide and bismuthide of cop- [per and lead.
Boulangerite.	"	Sulphide & antimonide of lead.
Pyrargyrite.	Hexagonal.	Sulphide & antimonide of silver.
Proustite.	"	Sulphide & arsenide of silver.
Pyrostilpnite.	Monoclinic.	Sulphide & antimonide of silver.
Tetrahedrite.	Isometric.	Sulphide & antimonide of copper.
Tennantite.	"	Sulphide & arsenide of copper.
Jordanite.	Orthorhombic.	Sulphide & arsenide of lead.
Geocronite.	"	Sulphide & arsenide of lead.
Stephanite.	"	Sulphide & antimonide of silver.
Polybasite.	"	Sulphide & antimonide of silver.
Enargite.	"	Sulphide & arsenide of copper.

CALCITE (Pseudomorph after Aragonite)
Sicily
Bement Collection, American Museum of Natural History

Realgar and Orpiment. These mineral species are respectively mono- and tri-sulphide of arsenic. The former occurs in very beautiful red crystals, which upon exposure break down into a pulverulent mass of orpiment (yellow), accompanied by an arsenic oxide (arsenolite, black). Specimens on this account are not generally shown in cabinets, but the ruins of several attractive realgars, completely altered to the yellow tri-sulphide, take their place. The realgars are often in perfect crystals from the Banat, with broad clino pinacoids, and domes, and prisms, also superb rich mulberry red crystals from Hungary.

Realgar occurs associated with silver ores in clay and limestone, and frequently in the products of exhalations from volcanic vents, as the examples on salammoniac show. Orpiment is less frequently found crystallized and occurs in seams in clay beneath the lava beds of Iron County, Utah.

STIBNITE, the sulphide of antimony, is a valuable ore of this metal and·affords the mineralogist very beautiful, lustrous and terminated prisms, usually clustered in radiating groups. Amongst the specimens in cabinets the striking groups of stout and long crystals claim attention. They were found with many other specimens, which supplied the cabinets of the world, at Mt. Kosrang, near Siejo, Province of Iyo, Shikoku Is., Japan, of which Prof. E. S. Dana says: "in the size and beauty of the crystals and in the great complexity of their forms, the Japanese stibnite far outrivals the specimens of the same species from other localities."

The Japan stibnites are remarkable in every way. Their luster is unsurpassed; the length of the crystals, some of which attain the extraordinary dimensions of twenty-two inches, is unequalled, while their grouping in clusters of sixteen or twenty divergent prisms, and their extraordinary diversity of crystalline faces, give them an unapproachable distinction. Previous to 1864 but sixteen planes had been identified. Twenty-nine new planes were added by Krenner and Seligman, making 45 in all. Thirty of these have been observed on the Japanese specimens, and as Prof. E. S. Dana records (*A. J. S.,* V. xxvi, p. 216): "*forty new planes have been determined,* thus increasing the list to *eighty-five.*" The crystals seem to have developed in cavities throughout a stratum of heavily-bedded stibniferous gneiss. One peculiarity of stibnite is its bending, and examples have been described which form a complete ring; in the Japanese crystals this bending is more limited to the terminations but sometimes proceeds so far as to form a right angle.

The Japanese crystals are sometimes twisted in a remarkable way. The mineral has a perfect longitudinal cleavage, and on a

cleavage face shows—by the unequal melting of wax in two directions—the unequal thermal conductivity of the mineral.

Molybdenite resembles graphite in appearance and its name, μολυβδος, means *lead,* with which graphite and antimony were, for some time, confounded. The collector can generally distinguish between it and graphite by the streak, which in the case of graphite is gray-black, but with molybdenite is bluish-gray on paper and on porcelain slightly greenish. Its blowpipe reactions at once identify it. It has been found in the gneiss and schists of New York Island as flakes or scales. Some handsome thick sheets have been taken from the island, one mass from 42d st. and 1st ave. in quartz, while specimens from Westmoreland, N. H., show the yellow oxide of molybdenum, produced by alteration of the sulphide. Molybdenite from Canada will be observed in beautiful hexagonal crystals with basal pinacoids and horizontal cleavage planes.

Argenite, the sulphide or silver, occurs in cubes and trigonal trisoctahedrons and rhombic dodecahedrons, and these forms are seen in specimens from Freiberg, Saxony, more or less distorted. Also filiform specimens produced by the sulphuration of wire silver. This is a common ore of silver and prevails in the Comstock Lode along with stephanite. Beautiful crystallizations come from Arizpe, Sonora, Meximo. The mineral exposed to a current of heated hydrogen or even steam is reduced to wire silver.

Galenite, the sulphide of lead, is the most important ore of that metal and one of the most interesting of minerals, the variety and perfection of its natural crystals giving it prominence in mineral collections. The cube, rhombic-dodecahedron, and octahedron are shown in great perfection; also peculiar crystalline elongations producing fibrous or reticulated surfaces from Galena, Ill., which make the "skeleton leads." A large group of cubes from Joplin, Mo., are often exhibited, which upon inspection are seen to be built up of smaller cubes blocked up into hexahedrons. Broad cleavage faces from Mineral Point, Wis., sometimes are shown wherein the cubical nucleus is apparent, and the square striations. Galenite appears in the specimens associated with calcite, siderite, fluorite, pyrite, quartz, and sphalerite, which point to its deposition from water.

From the Harz remarkably clear combinations of cube, octahedron and rhombic dodecahedrons are obtained by collectors; from Joplin, Mo., cubes are seen most interestingly built up of many smaller cubes, and it may often be observed that in the case of the truncated larger cubes, the small composing individuals show the same octahedral truncations, viz, the ends of the cubes are cut off by planes forming triangular faces. The faces of these larger cubes

are often warped or curved as the faces of the small cubes have not always developed quite identically on the same plane. Frequently hollow faces are seen of the octahedrons and incomplete layer-like building-up of the cube faces, sometimes crystals enclose each other, forming around some nucleal crystal; then again distorted octahedrons pushed out from one another in long columns, these latter in Galena, Ill., specimens. Simple octahedrons from Joplin, Mo., examples of parallel crystallization, a group of crystals being all identically positioned (*orientated*), sometimes however quite separated, again fine wires in parallel lines similar to the fluted gold (see above), being produced cubes; again pitted surfaces from Joplin, pitted (octahedral impressions) surfaces, also roughened by minute octahedral proturberances or cubical skeleton lines. An inspection of the large crystals gives the impression that they have been made up from a number of crystallizing centers, and that the finally confluent surfaces have not been altogether in one plane.

Galena is a very old name for this ore of lead and comes down to us from the days of Pliny. The development of this ore in the United States is extensive, being found in Missouri, Illinois, Iowa, and Wisconsin in seams, veins and beds. Its development is characterized by fissures and crevices, of which the greater number have an east and west, or north and south direction; the east and west being the largest and most productive (Moses, Strong). It occurs in sheets and in irregular enlargements, called "openings," and it has been deposited in the avenues of an extensive underground system of water drainage. In 1900 the United States produced 276,000 short tons; in 1906, 350,000 short tons of lead; in 1908, 311,000 were produced in the United States, in 1909, 355,000, valued at over $30,000,000.

Chalcocite. The crystals of this mineral are interesting from their twinning habits, "producing pseudo-hexagonal stellate forms," examples of which are shown from Cornwall, whence the finest crystallizations are obtained. The stellate forms arise from the symmetrical union of simple crystals interpenetrating towards a common center.

Chalcocite is a valuable ore of copper; large masses come from the famous Anaconda Mine at Butte City, Montana. It is extensively contaminated with iron pyrite. The Anaconda Company had a matte-making capacity in 1887 of $60,000,000 a year, and from Montana the copper product is practically concentrated in the Butte district. The veins are contained in granitic rock much broken and altered. About 90 per cent. of the output is chalcocite. Secondary

enrichment extends downward to 2400 feet in the Anaconda mine. Beautiful crystals of chalcocite come from Bristol, Conn.

Acanthite is like Argentite a silver-sulphide, but is separated from that mineral by its crystallographic form. It is considered orthorhombic, but Krenner points out that from its angles it may be only a distorted isometric form.

Sphalerite (zinc blende) is the commonest and most productive ore of zinc. The variety of its color is noticeable in cabinets from the honey-yellow, lime-green tints of the Spanish variety to the "black-jack" of Wisconsin or Missouri. Its crystals are hemihedral (Figs. 324 to 329) and its habit of twinning, its complex, distorted and rounded interpenetrations, etc., are repeatedly illustrated in collections. Some examples show that, as in the case of Galenite, its deposition was in connection with water action or from solution. Thus quartz shells are seen covered with cubical cavities made by the removal of Fluorite in solution, and the deposit in turn over these surfaces of small aggregates of Sphalerite
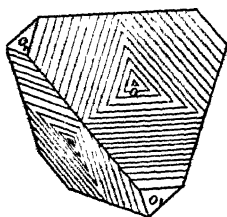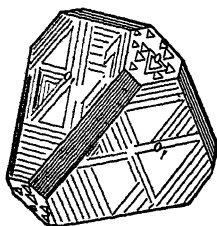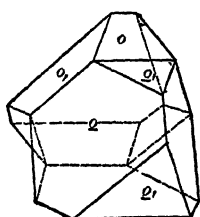

Fig. 324   Fig. 325   Fig. 326
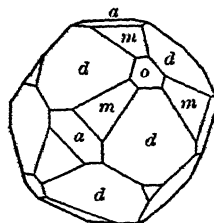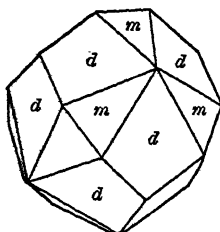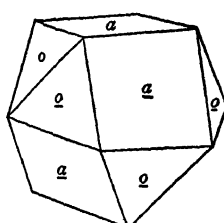
Fig. 327   Fig. 328   Fig. 329

PLATE 16

crystals. Such examples come from Joplin, Mo. The beds at Joplin, Mo., are of great extent, and the "original sphalerite in places have been removed and redeposited as calamine or smithsonite, or again as sphalerite, usually in crystals."
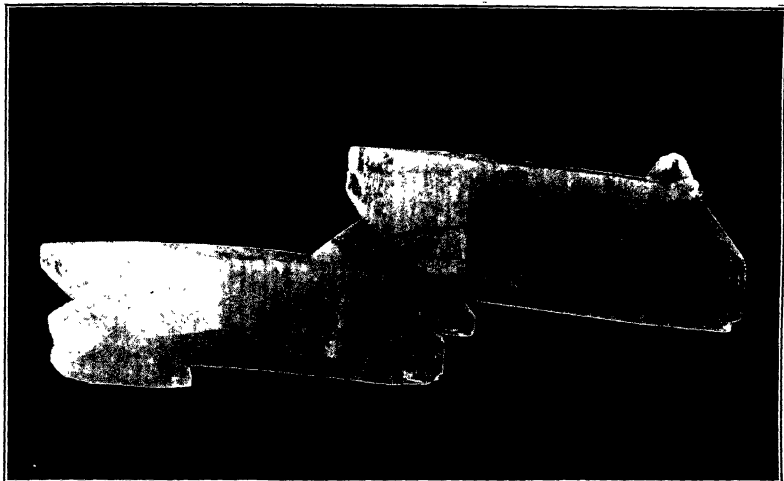
CALCITE (Twinned)
Guanajuato, Mexico
Bement Collection, American Museum of Natural History

CALCITE
Guanajuato, Mexico
Bement Collection, American Museum of Natural History

Sphalerite in attractive specimens is obtained in Transylvania, Hungary, Cumberland, England, Binnenthal, Switzerland, Joplin, Mo., Chester Co., Pa. A peculiarity often observed in Sphalerite is the building up of faces with triangular films, which form on one another like a series of faintly receding steps, which represent the oscillation of tetrahedrons. These sometimes appear as simply triangular rulings on the faces. Lovely clear twins from Binnenthal, Switzerland, occur made up of twinned sets of tetrahedrons.

Sphalerite has a perfect dodecahedral cleavage. Admixtures of iron and manganese color it. Iridium, gallium, tin, cadmium, thallium have been found in sphalerite. Cleiophane from Franklin Furnace, N. J., is pure and colorless. Sphalerite from Utah, light yellow concretions in gray massive sphalerite gives trails of phosphorescence of a yellow orange color when scratched with tip of finger, finger nail, piece of wood, brass wire brush, steel point (Levison). Almost $25,000,000 worth of zinc was produced in the U. S. in 1909.

Pentlandite a sulphide of iron and nickel a rare mineral mixed with pyrrhotite at Sudbury, Ontario. Platinum (Sperrylite) as an arsenide, and palladium, have been found in this association also.

Cinnabar is the ore of mercury from which the quicksilver of the world is obtained. It is of a beautiful carmine red, sometimes in scarlet pulverulent crusts or masses, and in mineral cabinets exhibited as translucent red crystals which are often twinned. Crystals hexagonal prisms, rhombohedral, sometimes trapezohedral terminations, with basal pinacoid. Taken in rolled nuggets from Borneo, superb interpenetrating twins from the province of Hu-nan, China, from Napa Co. Cal. Almaden Spain, Mt. Avala, Servia, Idria, Carniola Austria, and Felsobanya Hungary.

Greenockite, the sulphide of cadmium is an infrequent mineral and interesting, in crystallized forms, from its hemimorphism, the two ends of the hexagonal prisms being differently terminated. Taken at Greenock, Scotland, in yellow xtals on prehnite, also at Joplin, Mo., Franklin, N. J. Friedensville, Pa.

Millerite and **Niccolite** are respectively the sulphide and arsenide of nickel. The former is usually in slender needles, forming mosslike tufts or long hair-brown acicular groups, sometimes enrolled like a bunch of hair. *Niccolite,* a not dissimilar compound, is quite contrasted in appearance. It is massive, copper-red, and is not unlike a native metal when seen across broken surfaces. During the past few years numerous discoveries of nickel ore have been reported from various parts of the country, but chiefly in the State of Nevada. The sample from the greatest depth was nearly
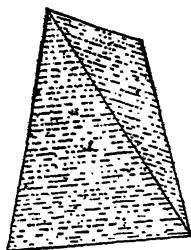
Fig. 330
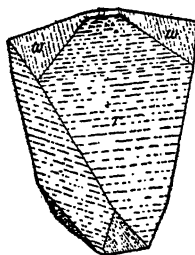
Fig. 331
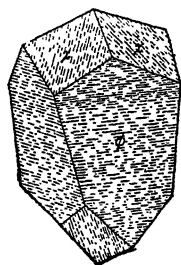
Fig. 332
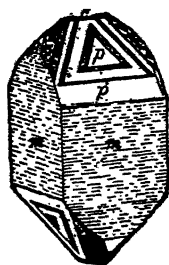
Fig. 333
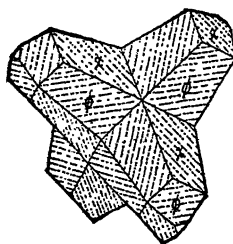
Fig. 334
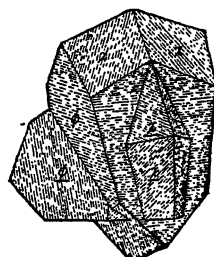
Fig. 335

Fig. 336
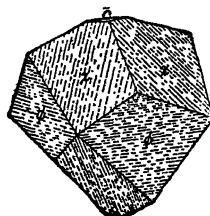
Fig. 337

PLATE 17

pure niccolite, which in the upper levels shows the effects of oxidation and hydration. These reports have been exaggerated. Sulphides of nickel have been found in Idaho, in Oregon, North Carolina, Mine La Motte, Mo. The Gap mine, Lancaster Co., Pa., was formerly a great producer of nickel sulphide. At present most of the nickel used in the U. S. comes from the nicoliferous ores of Sudbury Canada.

Breithauptite has been taken at Cobalt Ontario, Canada associated with silver and smaltite (R. B. Gage).

Pyrrhotite, a sulphide of iron having less sulphur than pyrite, is of a peculiar bronzy hue and is magnetic. It is doubtfully hexagonal in form. Large six-sided plates come from Morrho Velho in Brazil, crystals of excellent outline are found in quartz at Standish Me., and crystals from Saxony and Carinthia are prominent in collections.

Bornite, "horseflesh ore," *Erubescite,* pinchbeck lusters, blue tarnish, cubical in crystals, a good copper ore.

Linnaeite occurs in cubo-octahedral crystals at Müsen Prussia, is light yellow, and makes an interesting exhibit. The nickel in this mineral undergoes wide variations. When copper becomes a constituent it is Carrolite.

Chalcopyrite is one of the most common, and in its crystallography one of the most attractive copper minerals. It is a sulphide of copper and iron and is very widely distributed through gneiss rock and in schists generally. It forms remarkable areas in a metamorphic belt in Pennsylvania and is shown in beautiful crystals at the French Creek Mines, Chester Co., Pa. A group of the characteristic forms from this locality are given in Figs. 330 to 337, as determined and drawn by Penfield. A number of specimens from this locality are often exhibited in cabinets. The chalcopyrite occurs in calcite associated with very perfect octahedrons of pyrite and with a fibrous variety of hornblende known as *Byssolite.* The chalcopyrite occurs in *sphenoids* modified by *scalenohedrons,* and is striated on the faces, while the crystals become from this cause rounded. Much of the chalcopyrite from this locality is tarnished, an effect somewhat heightened in specimens by heating and treatment with acid. Capital examples of crowded and interlocked sphenoids are often exhibited. Crystals of much beauty were formerly taken out at the mines in Ellenville, Ulster Co., N. Y., and specimens always show its characteristic association with quartz.

Splendid large tetrahedrons on quartz, from Redruth and St. Agnes, Cornwall, England, are exhibited in collections; confused intersecting groups from Schemnitz, Hungary; capping blistered and mamillated surfaces from Redruth, Cornwall, England; tetrahedrons from Chester Co., Pa.; and conjoined prisms and pyramids from Ellenville, N. Y.

The angles of chalcopyrite crystals approach the isometric, and its sphenoids were at first confused with right and left tetrahedrons. A distinction, pointed out by Prof. Miers, is "that of the six tetrahedron edges only four are truncated, and this is suffi-

cient to show that the truncating faces belong to a square prism and not to a cube."

Pyrite, the bisulphide of iron, is one of the most widely distributed of the metallic compounds. It is found in almost all classes of rocks and is a common ingredient of mineral veins. Its crystallizations are well marked and often of much beauty, while its brilliant luster and golden color have given it a fictitious resemblance to gold, and frequently lead to its erroneous identification with that metal. Gold is indeed a common associate with pyrite, disseminated through it in almost invisible grains or dust, and the successful separation of gold from this gangue is to-day a metallurgical problem.

The common crystalline forms of pyrite are the cube and the hemi-tetrahexahedron (pentagonal dodecahedron) (Figs. 338 and
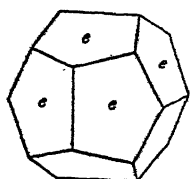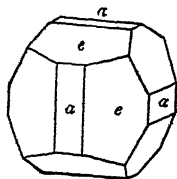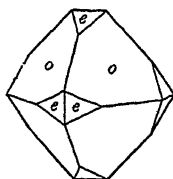
Fig. 338   Fig. 339   Fig. 340   Fig. 341
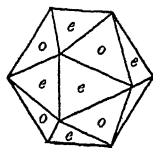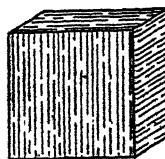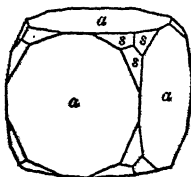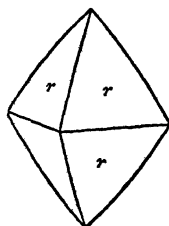
Fig. 342   Fig. 343   Fig. 344   Fig. 345
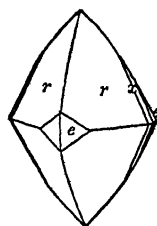
PLATE 18

345), sometimes called pyritohedrons. Examples of these forms are always seen from the Island of Elba and Traversella, Italy, Colorado and Nevada, while the more rare octahedrons are capitally exemplified in specimens from Elba, along with truncated cubes from the same locality, and in sharp, splendent crystals from French Creek, Pa. Balls of concretionary pyrite from Jacksonville, Fla., are noteworthy, wherein the crowded cubes display their edges on the spherical surface in irregular projections.

Examples of cubes altered upon the surfaces to limonite (hydrated oxide of iron) in thin films, from Chester Co., Pa., may be shown. This alteration is quite common in pyrite and consists in an oxidation of the iron with hydration and a removal of the sulphur, also oxidized, as sulphuric acid in waters carrying carbonate of lime in solution. Pyritohedrons altered to limonite in this way from Argeles Pyrenees, France, are often seen. The cubes are generally striated *i.e.* crossed by rulings, which vary from strong ridges to fine lines, and it will be noticed that, as in Fig. 342, these rulings make right angles with each other upon adjoining faces of the cube. This peculiar appearance arises from an intermittent effort on the part of the crystallizing substance to carry itself into the form of a pyritohedron, an effort which is, however, constantly repressed in this case, leaving the cube intact, but scored with these faint undulatory marks. Very peculiar octahedrons of pyrite have been found at French Creek, Pa., which are elongated in the direction of the vertical axis (*Amer. Jour.*, Vol. xxxvii, pp. 210, 211), appearing, as Mr. Penfield observes, as "steep tetragonal or orthorhombic pyramids." This distortion is unexplained. These curious forms Professor Penfield prefers to regard as abnormally developed trigonal trisoctahedrons. (From the Bement Collection.) (Figs. 344, 345.)

From Piedmont will be generally found in collections pentagonal dodecahedrons (pyritohedrons) with the cube and tetragonal trisoctahedron, also large octahedrons from Sweden, occasionally triangular elevations on the octahedral faces may be noticed; again Elba crystals of amazing perfection and distinctness, distorted cubes and octahedrons, curious pueblolike clusters of cubes, and cubes arranged in twisted or curved series, also particularly brilliant crystals from Colorado. Unusual planes (as rhombic-dodecahedrons) are well developed in the Colorado crystals and Prof. Krauss of Ann Arbor Michigan has measured a series of new forms and combinations. Prof. Miers states "it has been noticed that some pyritohedra have their faces striated parallel to the cube edges, and others (more rare) perpendicular thereto. Now it has also been proved that the former when warmed in contact with a copper wire give rise to an electric current which travels from the copper to the pyrites, or are thermo-electrically positive, whereas the latter are thermo-electrically negative or give rise to a current in the opposite direction."

Hauerite occurs in large and perfect crystals from Raddusa Sicily, where, it is found in a volcanic clay, as octahedrons, cubooctahedrons, or crowded together in masses.

Smaltite, Cobaltite, the arsenide and sulpharsenide of Cobalt, with a large admixture of nickel in **Chloanthite,** are important cobalt minerals, and the former, one of the oldest sources of cobalt in the United States, from the Chatham cobalt mine in Middlesex Co., Conn.   Both species crystallize in the Isometric System, and imitate the forms of pyrite.   Some good crystals of Cobaltite from Tunaberg, Sweden, may be shown, and amongst the Smaltites interesting specimens of reticulated smaltite from Schneeberg, Saxony.

Smaltite and Cobaltite are found at the new silver locality, Cobalt, in Ontario, Canada, and the former may be shown in specimens of arrow-pointed silver coating the latter with gray mineral.

Ullmannite; this mineral has been found at Sarrabus, Sardinia, crystallized in black cubes, with pyritohedral striations.   The specimens are very pretty.

Gersdorffite has been doubtfully regarded as a mixture of sulphides and arsenides of nickel; the mineral is isometric and adds another member to the remarkable isomorphous series of sulphides and arsenides.

Skutterudite is a tri-arsenide of cobalt and is also isometric.

Marcasite, like Pyrite, is a bisulphide of iron, but crystallizes in the Orthorhombic System.   It is less stable than pyrite, yielding more readily to oxidizing influences, changing to *copperas,* sulphate of iron, with comparative readiness.   It twins, forming pentagonal plates or arrow-shaped combinations (Dover, England, Schlaggenwald, Bohemia), which from the crestlike appearance have been called *cockscomb ore.*   The orthorhombic habit of the mineral is well shown in specimens from the Marsden Mine, Galena, Ills., where the successive circles of pyramids form above each other tower or pagodalike pinnacles.   In this famous locality, well represented in large collections, it occurs coating galenite, and in stalactitic crusts overlaying sphalerite.   Striking specimens are from Jasper Co., Mo.   An instructive specimen of marcasite altered to limonite, will be found, and fossil shells thinly veneered with fragile crusts of this mineral are often exhibited.

It seems probable that the very general distribution of sulphide of iron has resulted from its precipitation from iron solutions by sulphuretted hydrogen generated in the decomposition of animal and vegetable organisms.   Animals and plants contain sulphur and this becomes a sulphuretted gas upon their decay, which passing through iron waters throws down a certain amount of iron sulphide.   Sulphides also result from the reduction of sulphates to sulphides by organic substances, while in volcanic dis-

tricts the constant exhalation of sulphur fumes brings about the same results.

Marcasite unlike pyrite has not been artificially produced.

Arsenopyrite (mispickel), arsenide and sulphide of iron, will be illustrated in collections by specimens from Canada, Cornwall, Saxony and Connecticut, in characteristic rhombic prisms. It is very generally twinned; mixed with the arsenide of cobalt, *glaucodot,* it may contain 9 per cent of cobalt; it is grayish white in color; fuses to a magnetic bead.

Glaucodot and **Alloclasite** are cobalt sulphides with iron; the latter with arsenic and bismuth. The former in large octahedrons, elongated and striated cubes, is found at Hakensbo, Sweden.

Sylvanite, the telluride of silver and gold, a brilliant white mineral, is always represented by specimens from Transylvania, whence its name is derived, and in allusion to the use of *sylvanium* as a name for the element tellurium. Fine crystals are from Boulder Co., Colorado. Its reticulated filiaments on white quartz form handsome cabinet specimens.

Binnite is no longer considered a distinct mineral species, but is placed with Tennantite under tetrahedrite, occurring in brilliant modified cubic crystals—also hemihedral—on snow white dolomite.

Nagyagite in large and in minute intersecting plates from Nagyag, Transylvania; *Kermesite* in cochineal red fibres from Saxony and Hungary, often in quartz-lined crevices; *Emplectite* in steel-gray needles in cavities from Saxony, or striated yellow prisms; *Miargyrite* in small stout orthorhombic crystals from Zacatecas, Mexico, and Braunsdorf, Saxony; *Cosalite* (Bjelkite) in channeled prisms in calcite; *Dufrenoysite* in orthorhombic lead-gray glistening crystals in dolomite, from Binnenthal, Switzerland; *Jamesonite* in mats and crusts of interlacing black-gray shining fibres, with the clustered *Cylindrite,* a tin and lead sulphide, looking like black-lead, from Bolivia, S. A. come near each other in the mineral succession.

Freieslebenite in fine crystals from Hiendelencina, Spain, can be seen; a mineral somewhat rare in good crystals.

Bournonite, the sulpho-antimonide of lead and copper, in beautiful crystals from Liskeard, Cornwall, are often shown. These are twins formed by the coalescence along prismatic planes of separate crystals.

This twinning gives rise to cross-shaped and cog-wheel groups; sometimes called "wheel-ore," twinning lamellae show on a fractured surface in the *massive* mineral.

Pyrargyrite and Proustite are important silver minerals; the first is a sulph-antimonide of silver, the second a sulph-arsenide; both crystallize in the hexagonal system and in hemihedral forms. *Pyrargyrite* of good quality from Andreasberg, Hartz, and Freiberg, Saxony, are shown in cabinets; the rhombohedral summits and hexagonal prisms being conspicuous. *Proustite,* much valued by collectors on account of its brilliant hue, with aurora red reflections by transmitted light, may be well represented, and examples from Chanarcillo are especially attractive. The tapering blades from this locality are made up of scalenohedrons terminated by low rhombohedrons.

Pyrargyrite is often seen in bunched prisms with basal rhombohedrons from Mexico, and from Andreasberg in prisms, with low pyramids of scalenohedrons from the Harz. The Proustite from Chili will be seen in long fluted crystals with projecting spikes of smaller crystals, like a Hercules club; often acute and obtuse rhombohedrons of a deep cochineal transparent tint; also in deeply-channeled prisms.

The similarity of Pyrargyrite and Proustite is obvious, and Prof. H. A. Miers undertook an exhaustive examination of the specimens in the British Museum to determine whether they were good species. He found them sharply separated but it was pointed out that with an increasing admixture of arsenic in Pyrargyrite the angles of the crystals approached those of Proustite. A separation he suggested, of use to the amateur, is made by their respective colors in transmitted light. Pyrargyrite is reddish purple and Proustite cinnabar red, which distinction holds also in their streaks.

Pyrostilpnite is a rare and very delicate species and its grouped, tufted, tabular crystals on galenite and with pyrargyrite, are frequently seen, but are expensive mineral features.

Tetrahedrite, the sulph-antimonide of copper, with a varying admixture of silver, iron, mercury, zinc. and lead, is so-called from its assumption of the tetrahedral form, which makes it so characteristic and distinct a mineral. Beautiful examples are often exhibited, many of which have their surfaces altered into chalcopyrite, in association with quartz from Kapnik, Hungary, and Cornwall, England. Owing to its variable composition, its number of alterations is large, extending to chalcopyrite, malachite, azurite, amalgam, bournonite, erythrite, cinnabar, and covellite. Its variable composition arises from the replacement of copper by mercury, silver, iron, zinc. *Tennantite,* very near tetrahedrite, is darker and apt to be cubic or dodecahedral. *Freibergite* is an argentiferous tetrahedrite, and *Schwatzite* a mercurial variety.
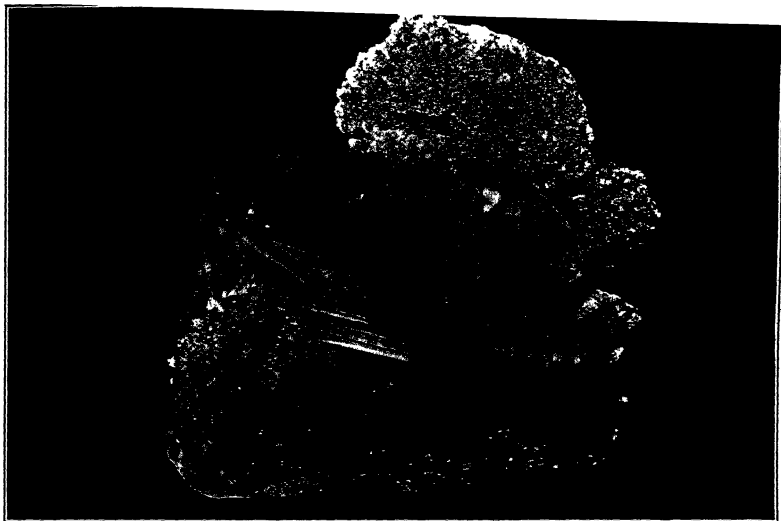
CALCITE OVER COPPER
Hancock, Houghton Co., Mich.
Bement Collection, American Museum of Natural History
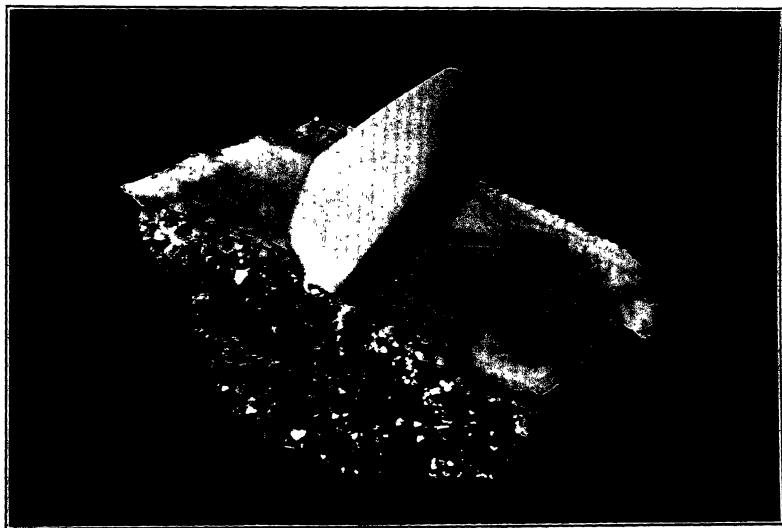
CALCITE ON AMETHYST
Guanajuato, Mexico
Bement Collection, American Museum of Natural History

Stephanite and Polybasite are important ores of silver and the former possesses interest from being an abundant ore of silver in the Comstock lode, Nevada. Both form beautiful crystallizations, the former in hexagonal prisms from twinning, the latter more tabular in beveled plates. Both minerals are found in extreme perfection of crystallization at Arizpe, Durango Mexico. (E. L. Dufourck).

In this section *Argyrodite* may be mentioned, a most unusual mineral, containing the element *germanium,* occurring in Bolivia; *Canfieldite* an argyrodite carrying *tin,* and *lorandite* a *thallium* (60%) mineral in red crystals at Allchar in Macedonia, Greece. *Enargite* is found in handsome crystals in Colorado and is the parent mineral of arsenates, formed by its oxidation.

The groups of Haloid Compounds follow the foregoing divisions, and is composed of the unions of the elements Chlorine, Fluorine, Iodine, Bromine, with basic atoms of the metals, with admixture of oxygen, making oxy-salts, and of combined water, making *hydrous* salts. As represented in a collection they are grouped as follows:

HALOIDS

Anhydrous Chlorides, Bromides, etc.

Species.	*System.*	*Composition.*
Calomel.	Tetragonal.	Chloride of mercury.
Halite.	Isometric.	Chloride of sodium.
Sylvite.	"	Chloride of potassium.
Sal Ammoniac.	"	Chloride of ammonium.
Cerargyrite.	"	Chloride of silver.
Embolite.	"	Chloride & bromide of silver.
Bromyrite.	"	Bromide of silver.
Iodyrite.	"	Iodide of silver.
Fluorite.	Isometric.	Fluoride of calcium.
Cotunnite.	Orthorhombic.	Chloride of lead.
Molysite?	Hexagonal.	Chloride of iron.
Cryolite.	Monoclinic.	Fluoride of aluminum and sodium.

Oxychlorides, etc.

Species.	System.	Composition.
Matlockite.	Tetragonal.	Oxychloride of lead.
Atacamite.	Orthorhombic.	Oxychloride of copper.
Nocerite.	Hexagonal.	Fluoride of calcium and magnesium.
Fluocerite.	"	Fluoride of Cerium, Lanthanum, etc.
Fluellite.	Orthorhombic.	Fluoride of aluminum.
Prosopite.	Monoclinic.	Fluoride of calcium and aluminum.
Pachnolite. } Thomsenolite. }	"	Fluoride of sodium, calcium, and aluminum.
Gearksutite.		Fluoride of calcium and aluminum.
Yttrocerite.		Fluoride of calcium, with yttrium and cerium.

Halite, common salt, is the chloride of sodium and is extensively found in basin deposits in rocks of varying ages, where concentration of saline waters has precipitated it in more or less heavy beds. It occurs in India in the Salt Range in immense layers, attaining a thickness of from 257 feet to 275 feet, and in other localities (Kohát district) it is found exceeding 1,000 feet in thickness. In western New York it probably occurs at a depth of from 1,000 to 2,000 feet, in thick strata, from which the salt is extracted by saturating water, making salt brines from which the salt is obtained by evaporation. These deposits extend north and south and are met with in Canada. Other important beds are those of Poland, Stassfurt, Germany, and Cheshire, England. Perhaps in the latter locality it is almost pure, being found in spherical concretions, which are crushed and the salt shipped for use. In Nevada it is also of great purity. Salt crystallizes in cubes, rarely octahedrons, and these cubes have hollow faces (hopper shaped); being completely soluble it is often removed by solution in water and its cavities filled with secondary deposits, as gypsum, quartz, hematite, pyrite, dolomite, celestite. The specimens of Halite from Girgenti, Sicily, Bex, Switzerland, and the clear masses from San Domingo, W. Is., will be noticed as good examples of crystallization, and the hollow crystals shown in the specimens from Los Angeles, Cal., while examples of the crystallization around sticks from the supersaturated waters of the Great Salt Lake, Utah, may be looked for.

Salt mining was begun in western New York in 1886 at a depth of 1,000 feet, where a stratum of salt twenty-two feet thick, four-

teen feet of which is pure salt, was encountered. The salt is very pure. Strata of salt above and below were met, making in all eighty feet of solid salt within a distance of two hundred feet. This was in Livingston Co., N. Y.

Salt is often stained yellow, blue, or red, and these colorations, especially blue, are not easily explained; the blue has been ascribed to a lower chloride of sodium, to sulphur, and to interference from included cavities.

In 1906 the quantity of salt produced in the United States was 28,172,380 barrels of 280 pounds, valued at $6,658,350. The principal producing states are New York, Michigan, Ohio, Kansas, Louisiana, California, West Virginia, Texas, Utah. In 1909 its value was $8,400,000.

Sylvite is a beautiful mineral found in exquisite examples at Stassfurt in Galicia. It is more modified than *halite,* and is commonly in truncated cubes, delicately shaded.

Sal Ammoniac, the chloride of ammonium, is found in the exhalations from Vesuvius, and specimens from that volcanic region are often exhibited.

Cerargyrite, Embolite, Bromyrite, and **Iodyrite** are silver minerals of some importance; the first, known as horn silver, cuts like wax, and is commonly found as a crust or in columnar masses. Bromyrite, Embolite and Iodyrite, the former two especially, are well developed at Chanarcillo, Chili.

Embolite occurs in isometric forms (cubes, octahedrons, rhombic-dodecahedrons) in brown crystals on stalactitic manganese oxide at the Broken Hill Mines, New South Wales, while *Iodyrite* in unusual hexagonal prisms, greenish yellow, are taken in the same locality.

Fluorite, fluoride of calcium, is one of the most beautiful of minerals and forms an important feature in mineral cabinets. Although its form (the cube) is predominantly unvaried, its great variety of tints, delicate shades, and attractive associations, make it a fascinating species. The cabinet of any museum contains a great number of contrasted and striking specimens illustrating the wide range of colors it assumes. Some of the less common modifications of form will also be shown, *i e.* the octahedral fluorite from Andreasberg, Hartz; that from Grimsel, Switzerland; in an amygdule (almond shaped cavity) from the trap, north shore of Lake Superior; on hornblende from Vesuvius and from Devonshire, England, while examples with albite on orthoclase from Baveno, Italy, are especially interesting. The cube, octahedron and rhombic dodecahedron, in conjunction, occur on specimens from St. Gothard, Switz.; the tetrahexahedron and cube from Liskeard,

Cornwall, and the hexoctahedron in modifying faces from Cornwall.

Fine large groups are frequently exhibited from Macomb, N. Y., which were taken from a large cave "lined with cubic crystals of a sea-green color, from one to six inches in diameter, some of the groups weighing 1,000 pounds, and the whole cavity estimated to contain 15 tons." With this group are many others from Cornwall and Cumberland, England.

The physical qualities of fluorite give it an added interest. It is slightly fluorescent, phosphoresces when heated, is contrastedly electrical under the action of heat and light on the edges and faces of the cube, exhibits double refraction (anomalous in the isometric system), attributed to internal tension, and upon etching develops peculiar depressions. The colors of this mineral are ascribed to the presence of compounds of carbon and hydrogen. (Wyrouboff.) Its perfect octahedral cleavage distinguishes it, the green and red crystals phosphoresce; the low tetrahexahedron seen on cubic faces has been called "the fluoroid" from its prevalence in fluorite. It is frequently twinned by interpenetration of cubes, octahedral faces are dull; it fuses easily, hence used as a flux, and its name is derived from *fluo* to run or flow. It is a common associate of ores in veins, sometimes in parti-colored layers.

Fluorite in large collections offers a splendid display of colors and associations. In the Bement Collection, at the American Museum of Natural History, the series of specimens are especially attractive. From Cumberland, England, there are elongated cubes with attached calcite crystals, large cubes coated with a frostlike encrustation of quartz, purple and green cubes densely ruled with fine lines, which indicate oscillation of the tetrahexahedron, green cubes from Cornwall with feathery edges of purple, inclusions of black specks and interior colored boundaries (phantoms), also octahedrons and tetrahexahedrons; from Brienz, Switzerland, low scolloplike depressions, pyramidal pits, wrinkling lines, finely made pin-point holes, the whole looking like an eroded or half-melted ice-block; from Saxony, yellow cubes with galenite, magnificent pink octahedrons from Switzerland, some of these with blunted, rounded angles made by vicinal planes of trigonal trisoctahedrons.

Boleite has in recent years been added to collections from Boleo Lake, Lower Calif. It occurs in beautiful blue colors, and is crystallized in pseudo-cubes.

Cryolite, the double fluoride of sodium and aluminum, occurs in a bed in granite at Ivigtut, West Greenland, displaying crystals along the surfaces of the seams or cracks in the massive mineral. It is here found enclosing quartz, siderite, galenite, sphalerite, pyrite, chalcopyrite and wolframite. The mineral is mined in large

ARAGONITE (Flos Ferri)
Styria, Austria
Bement Collection, American Museum of Natural History

quantities and its exportation constitutes a special trade; it is used in the manufacture of aluminum and a very pure carbonate of soda. Specimens from this typical locality are shown in the cases. It is found at the base of Pike's Peak, Colo., and has been reported from Yellowstone Park, Wyoming. It fuses in the flame of a candle and has cubical cleavage. Its cubical appearance is deceptive. *Matlockite* in yellow tables from Matlock England, and in spheres of intersecting plates; *Atacamite* in stout dark green crystals, or silken plushlike surfaces from Chili; the curious oxy-chloride of lead, *mendipite; chiolite, laurionite, fiedlerite, percylite,* with *Prosopite* from Saxony, occurring with cassiterite; and the unusual oxy-iodide of lead, *Schwarzenbergite,* follow.

Pachnolite, Thomsenolite and Prosopite are of interest to the mineralogist as alteration products of Cryolite and especially from recent "finds" in Colorado. The examples in cabinets are characteristic. Gearksutite, nearly related to both, is distinguished by its chalky appearance.

The Oxides follow the simple compounds of the metals and semi-metals, and represent the union of oxygen with metallic bases. They form one of the most important classes of minerals, and amongst them are found many of the valuable ores, whilst quartz, as the oxide of silicon, is the most pervasive and universal of all the rock-making minerals. They are conveniently divided into two sections, those of Anhydrous and Hydrous Oxides.

ANHYDROUS OXIDES

Species.	System.	Composition.
Cuprite.	Isometric.	Oxide of copper.
Periclasite.	"	Oxide of magnesium.
Zincite.	Hexagonal.	Oxide of zinc.
Massicot.		Oxide of lead.
Melaconite.	Triclinic.	Binoxide of copper.
Corundum.	Hexagonal.	Sesquioxide of aluminum.
Hematite.	"	Sesquioxide of iron.
Menaccanite.	"	Oxides of iron and titanium.
Perofskite.	Isometric.	Oxides of titanium & calcium.
Spinel.	Isometric.	Oxides of magnesium and aluminum.
Gahnite.	"	Oxide of zinc and aluminum.
Magnetite.	"	Proto-sesquioxide of iron.
Magnesioferrite.	"	Oxides of magnesium & iron.

Species.	System.	Composition.
Franklinite.	"	Oxides or iron, zinc and manganese.
Chromite.	"	Oxides of iron & chromium.
Uraninite.	"	Oxide of Uranium.
Chrysoberyl.	Orthorhombic.	Oxides of beryllium and aluminum.
Cassiterite.	Tetragonal.	Oxide of tin.
Rutile.	"	Oxide of titanium.
Octahedrite.	"	Oxide of titanium.
Hausmannite.	Tetragonal	Oxide of manganese.
Braunite.	"	Oxide of manganese w. silica.
Minium.	"	Oxide of lead.
Brookite.	Orthorhombic.	Oxide of titanium.
Pyrolusite.	"	Oxide of manganese.
Senarmontite.	Isometric.	Oxide of antimony.
Valentinite.	Orthorhombic.	Oxide of antimony.
Bismite.	"	Oxide of bismuth.
Molybdite.	" ferrated.	Oxide of molybdenum.
Kermesite.	Monoclinic.	Oxide of antimony with sulphur.
Cervantite.	Orthorhombic.	Oxide of antimony.
Stibiconite.		Oxide of silicon.
Quartz (agate, jasper, chalcedony).	Hexagonal.	Oxide of Silica.

HYDROUS OXIDES

Species.	System.	Composition.
Diaspore.	Orthorhombic.	Sesquioxide of aluminum.
Turgite.		Sesquioxide of iron.
Chalcophanite.	Hexagonal.	
Göthite.	Orthorhombic.	Sesquioxide of iron.
Manganite.	"	Sesquioxide of manganese.
Limonite.		Sesquioxide of iron.
Beauxite.		Sesquioxide of aluminum.
Brucite.	Hexagonal.	Oxide of magnesium.
Hydrotalcite.	"	Oxides of magnesium and aluminum.
Gibbsite.	Monoclinic.	Oxide of aluminum.

Species.	*System.*	*Composition.*
Limnite.		Oxides of calcium & barium.
Gummite.		Uranium with silica.
Psilomelane.		Oxides of manganese & barium.
Reissacherite.		
Hetaerolite.		
Wad.		
Opal.		Oxide of silicon with water.

Cuprite, the suboxide of copper, commonly crystallizes in octahedrons, but it assumes other forms, the cube and dodecahedron, and in these instances it is often highly modified. The cubes are frequently lengthened into long, needlelike hairs, in which condition the beautiful *Chalcotrichite* occurs from Cornwall and Arizona. In collections fine cubic crystals, with hollow faces, are exhibited from Chessy, France, superficially coated with malachite, into which the cuprite is readily changed. The octahedral and cubo-octahedral crystals from Cornwall, the ruby octahedrons from Clifton, Arizona, the association with malachite from Bisbee, and the sparkling octahedrons from Clifton, are attractive and characteristic examples of this species. Cuprite alters to the higher oxide *Melaconite,* and it also undergoes a singular deoxidation by which it becomes changed to native copper.

Zincite, the oxide of zinc, has a very local interest; except as a furnace product it is not known in a state of nature outside of New Jersey. Until 1886 crystals of *Zincite* had been studied only in the artificial forms, the natural mineral being massive, with basal and prismatic cleavage, but at that time crystals were described from the cabinet of Mr. C. S. Bement, which consisted of a six-sided (hexagonal) pyramid, terminating a low six-sided prism resting on a base plane. Capital specimens of this valuable zinc ore can be seen in collections, showing its curved massive laminæ embedded in calcite (also containing zinc), from Franklin and Sterling, N. J. The rich red color is attributed to enclosed scales of hematite (red oxide of iron). (A. A. Hayes).

Manganese oxide is a common admixture in zincite, giving it a yellow or orange color. Mottled mixtures of zincite, franklinite, and willemite, (all zinc ores) occur in New Jersey. The eye next encounters the yellow *Massicot* in crusts; *tenorite* (melaconite) from Lk. Superior in black nodules, or in glistening scales from Vesuvius, with *para-melaconite* in striated prisms, associated with blue *footeite* (a copper salt) from Bisbee Arizona, precede the corundum.

Corundum, the sesquioxide of alumina, furnishes the lapidary and jeweller some of the most precious and beautiful examples of their art; this mineral is the source of the ruby and sapphire, and while in its more rare forms it constitutes these splendid gems, in its common occurrence it provides, for industrial uses, the valuable emery for whetstones and polishing wheels. Corundum is extensively developed in western North and South Carolina, stretching in a belt from Virginia to Alabama, and occurs in beds in chrysolite, serpentine and hornblendic gneiss, often upon a scale of surprising magnitude. A number of characteristic examples of corundum from North Carolina are invariably exhibited, amongst which the cleavage masses are of interest, and the well-marked hexagonal pyramids.

Corundum displays varying mineralogical associations in different regions. At Chester, Mass., where large *emery* mines are worked, rutile, magnetite, diaspore, margarite, and corundophyllite and epidote are accompanying minerals; in New Jersey at Franklin, Newton and Vernon, spinel, chondrodite, rutile, biotite in a dolomitic limestone; in Pennsylvania, in Delaware and Chester counties, tourmaline, margarite and albite; in North Carolina and Georgia, zoisite, ripidolite, albite, arfvedsonite, chrysolite, margarite. (C. U. Shepard.)

Professor Shepard's remarks on the characters of North Carolina corundum crystals are of interest. He says: "The crystals are generally rather remarkable for their translucency and internal regularity, their unfitness for cutting, therefore, would appear to result from their too easy cleavage rather than from other causes. The same crystal often combines the red and blue shades of color; the latter tint, if the form is pyramidal, being the deepest at the base, and evincing a tendency to traverse the center of the crystal, nearly to its apex, where the ruby color wholly replaces it, and sometimes here presents itself with much intensity. The faces differ considerably in smoothness and luster. Those belonging to the prism, the primary rhombohedron, and the face perpendicular to the axis being the most perfect, while those of the pyramid are the most deficient in finish." The double pyramids from Ceylon or N. Car. are irregular, indented, and roughened. The Montana sapphires are hexagonal prisms with basal plane, of a beautiful soft blue, and extracted from a trap (igneous) rock. As a gem stone corundum exhibits a surprising range of color, blue, red, amethystine, yellow, salmon tinted, white, greenish, with intermediate shades, and bronzy reflections. The star-sapphires so much valued result from "tubular cavities arranged in planes parallel to the
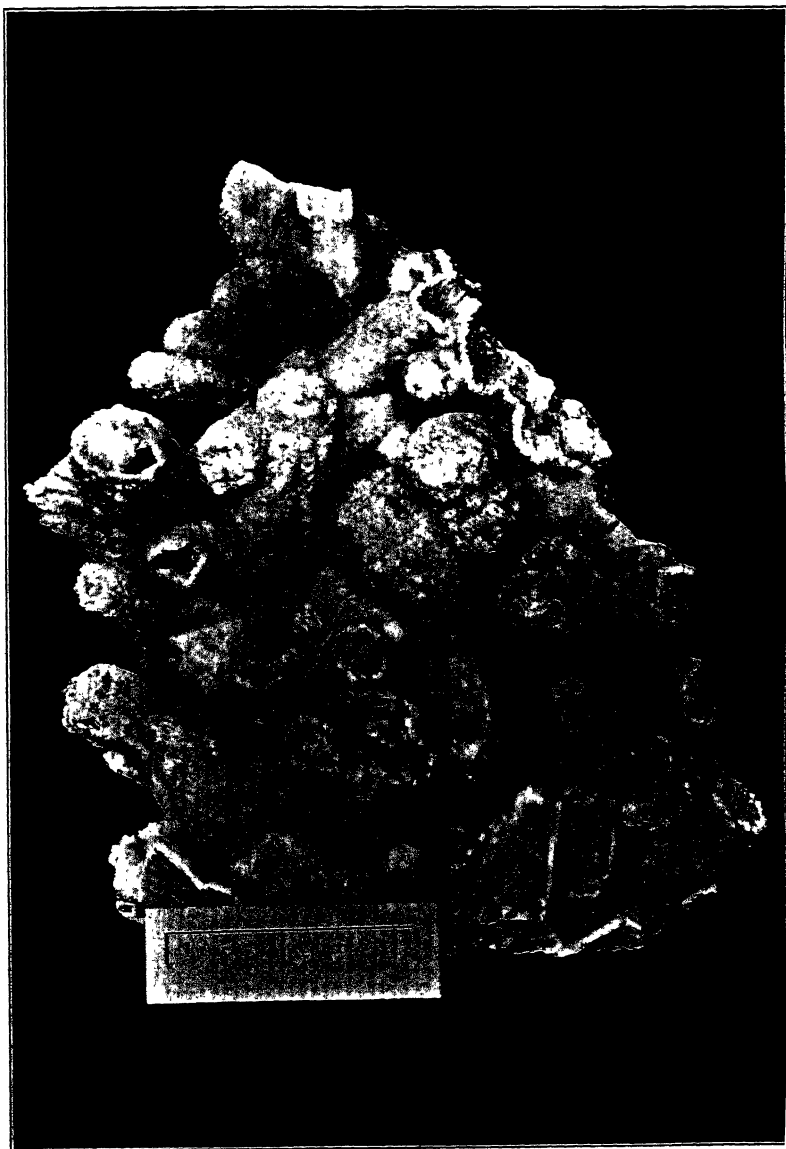
ARAGONITE (pseudomorphous)
Cianciana, Sicily, Italy
Bement Collection, American Museum of Natural History

prism" (Miers). It is dichroic, in ruby the colors are red and violet-red, in sapphire deep-blue and greenish-blue.

The surface of corundum is often altered into hydrated products, as silvery scales of margarite and damourite, and it is much found with aluminum hydrates, as bauxite, diaspore, gibbsite.

Hematite, the sesquioxide of iron, is one of the most common iron ores and disseminated through almost all soils and earths, contributes color to the landscape, and forms in rocks a pervasive coloring substance also. Its crystals (rhombohedral) are often of great beauty, with lustrous or iridescent surfaces, and its specular (mirrorlike) micaceous forms are brilliant features in the cabinet. The beautiful specimens from the Island of Elba, Italy, with their striated faces, blue and iridescent tarnish, and the exquisite rosettes or nests of embracing crystals from Selva, Switzerland, are noticeable in any cabinet. Less beautiful but of scientific interest are pseudomorphus crusts, which have been coated over calcite, from Westphalia, the included scales in quartz from Zinnwald, Bohemia, the altered magnetite (Martite) from Digby's Neck, Nova Scotia, and the micaceous knobs from Marquette, Mich.

The hematites from St. Gothard, Switzerland, and from Rio Elba are always seen in large collections. They occur in superb, splendent groups, generally rhombohedrons, a series of crystals imbedded upon one another like saucers, also scalenohedrons and rhombohedrons developed together in thick crystals from Rio Elba, and curious flat overlapping films or crusts from Maderia.

The famous hematite deposits in Marquette, Mich., are perhaps the most productive of all the iron-ore deposits in the country. The Menominee range, the Vermillion Lake iron district, Minnesota, Gogebic region, Michigan, and the "Iron Mountain" region of Missouri, are other large and wealthy fields. These deposits have resulted from stratified beds of ore, originally of marsh origin, which were formed at the same time with the enclosing rocks, and underwent metamorphism, or a change to the crystalline condition.

Near hematite the visitor finds **Menaccanite,** a mixture of the protoxide and sesquioxide of iron, with titanic oxide, a black rhombohedral mineral distributed in plates, grains and crystals, and also in beds through metamorphic rocks. Magnesia has been found in this mineral and it may be a titanate. Gigantic elongated crystals are taken at Froland (Kragerö), Norway. Titanium is closely associated with iron oxides in nature, and hematite often contains it, as well as the titaniferous magnetites.

Perofskite (Perovskite) has been placed with the oxides though now regarded as a titanate of lime. It is cubic in habit, as found at Zermatt or in the Urals, while the closely related *Dysanalyte*

of Magnet Cove, Arkansas, is octahedral. Excellent examples of both forms will probably be seen.

Spinel is an octahedral mineral and from its well defined crystals, its twinning and variety of color, forms an attractive species. It occurs in limestone, in gneiss and metamorphic rocks, where it has been developed by the heat coincident upon metamorphism. It is found to-day in masses ejected from volcanoes. As ruby-spinel it forms a gem. Specimens from Amity, New York, are representative, and the twins and distortions from Franklin and Hamburg, N. J., illustrate the twinning habit of the species. Spinel in octahedral groups from Monroe, N. Y., in calcite and with pyroxene from Stirling and Monroe, N. J., somewhat distorted, and in octahedrons from Orange Co., N. Y., are common in large collections.

It is interesting to note that spinel xtals, developed in limestone, have rounded edges, and it often appears corroded. Large crystals, now rare, come from Orange Co. N. Y.

Magnetite, the union or protoxide and sesquioxide of iron, is a valuable ore and a striking mineral. It is usually octahedral, modified by rhombic planes, which in their effort to impress themselves upon the crystal give rise to striæ, which may be seen on the specimens from Piedmont and Siberia. The glistening interpenetrating octahedrons from Chester Co., Pa., are attractive, and the twinning habit similar to that of Spinel often shown in specimens from Monroe. Magnetite in striated rhombic dodecahedrons from the Tilly Foster mine, Brewsters, N. Y., rare and fine, the cleavage masses from Essex Co., N. Y., the lustrous pyramids from Binnenthal, Switz., and roughened pyramids from Henry Co., Va., are often seen.

Octahedrons of magnetite in chlorite from Vermont, and coated with the appressed sheets of the mineral, from the Tyrol, are worthy of attention, if found. *Martite,* the hematitic phase of magnetite, produced by the oxidation of the protoxide, is strikingly illustrated in a dodecahedral form from Nova Scotia. Magnetite, so named from its polar qualities, does not always evince magnetic properties, but the lodestone from Shepard Mountain, Mo., displays this power; the stronger natural magnets come from Siberia, the Hartz and the Island of Elba. Frequently there may be noticed a series of cleavage fragments, sharply terminated, octahedral (distorted) forms, taken on Lake Champlain, N. Y. These have a peculiar interest. The parting seems an octahedral cleavage, but has been explained by Prof. J. F. Kemp as due to dynamic movements, to which the beds containing them have been subjected; a cleavage, in other words, *developed by pressure.*

Franklinite, made up of the oxides of iron, zinc and manganese, is a well developed octahedral mineral, usually with edges modified by dodecahedral planes, and the examples from Franklin Furnace and Stirling Hill, illustrate its common occurrence and association with willemite and zincite.

Chrysoberyl, beryllium aluminate, is the mineral substance which furnishes the beautiful Alexandrite gems, and the yellow chrysoberyls so prized by the jeweler. A peculiarity of the species is the twinning habit, shown in specimens from the Ural Mountains, Russia, where a stellate grouping of six individuals produces turbinate forms with striated summits.

It is found in flattened yellow plates with truncating faces in granite. Dr. Levison of Brooklyn possesses a rare specimen from a granite on Manhattan island; it has been broken by the crystallizing quartz in which it is embedded, and its parts shoved away from each other yet retaining their complementary fractures unchanged.

Cassiterite, the oxide of tin, is the common ore of that metal, and while limited in its occurrence as an ore, is more or less widely distributed in crystals through granite, gneiss, and micaceous schists. The crystals from Schlackenwald, Bohemia, with the geniculated forms from Graupen, Bohemia, show characteristic twinning, and the replacement of orthoclase from Cornwall is one of the most curious instances of mineral substitution.

This ore of tin has a characteristic association with fluorine-holding minerals as apatite, topaz, tourmaline, fluorite, zinnwaldite, and with them are found quartz, beryl, scheelite, wolframite, axinite. Violet artificial crystals of tin are formed in tin works but are not twinned, an almost invariable habit in nature. From its hardness and weight, tin-stone in rolled sand and nuggets forms in stream beds. Alaska, California, N. Car. S. Car. S. Dak. Idaho and Texas, contain tin-deposits, at present of insignificant value.

Rutile, the dioxide of titanium, occurs in a great number of crystalline rocks, and from its varying color, its associations and "elbow" (geniculation) grouping, forms a salient feature in mineral cabinets. Perhaps amongst the most beautiful of its occurrences are the penetrations of pellucid quartz by the long hairlike needles of rutile, the *fleches d' amour* or Sagenite, so familiar to connoisseurs. Amongst specimens, the reticulated group from Switzerland, the twinned crystals from Grave Mountain, Ga., curved crystals from Piedmont, Italy, crystals in mountain leather from Siberia, exquisite reticulations on quartz from Burke Co., N. C., and Tavetsch, Switzerland, claim notice. Messrs. Hidden and Washington have pointed out the interesting fact that in N. C. the "rare basal plane on the rutile and the predominance of the acute rhom-

bohedron on the associated quartz crystals, are good indications of the gem variety of spodumene (hiddenite), in Alexander County."

The dioxide of titanium is trimorphic, it appears in nature in the tetragonal form of rutile and the orthorhombic forms of *Octahedrite* and *Brookite,* both of which species are found in cabinets.

The Octahedrite crystals implanted upon quartz from Switzerland, are particularly effective and pretty, and the stout octahedrons of Brookite from Magnet Cove, Ark., and the flat plates from Ellenville, N. Y., show the crystalline phases of this protean species.

The so-called *Anatase* is most beautifully shown, and has a dainty perfection, crowding on quartz faces like crystallized minute honey grains.

Pyrolusite, Braunite, Manganite, are manganese oxides, which with the amorphous concretionary deposits known as *Psilomelane* and *Wad,* constitute the sources of manganese in the industries. They form in the crystallized species, especially Manganite, interesting and attractive specimens, and the latter species is illustrated by penetration twins and stout pyramidally terminated prisms from Ilefeld, Hartz. It has been urged with some force (F. P. Dunnington) that the deposit of manganese oxides has been effected by the action of iron sulphates in solution changing the disseminated manganese oxides of the rocks to sulphates, which again in contact with carbonate of lime have become concentrated in beds as oxides. The manganese ores occur as beds, but in many localities (Barmouth and Harlech, England) the undecomposed ore contains the manganese in the form of carbonate, with a small proportion of silicate.

Psilomelane is a hydrous oxide, invaded by variable amounts of sodium, potassium, and barium. It is surprisingly hard, its hardness is greater than that of manganite. Curious stalactitic formations of it with attached spheres, are found at the Bonnie Mine, Ironwood, Michigan. Prof. Miers asserts that *Manganite* crystals soften by dehydration and become pyrolusite, and crystals regarded as pyrolusite are pseudomorphs after manganite. Pyrolusite is exhibited as radiating black needles, terminating in crystalline faces. The view of its pseudomorphous origin is coincided with by Dana.

Minium, in vermilion crusts and masses, from New South Wales and Colorado, *hausmannite,* well crystallized from Ilmenau Thuringia, Ilefeld, Hartz, *braunite* from Krageroe, Norway, St. Marcel, Piedmont, and Långban, Sweden, figure among the anhydrous oxides in attractive groups of crystals or specimens.

Quartz is the most prized, the most beautiful and the most varied of all the minerals; in color, form and physical constitu-

CERUSITE

Broken Hill Mine, New South Wales

Bement Collection, American Museum of Natural History
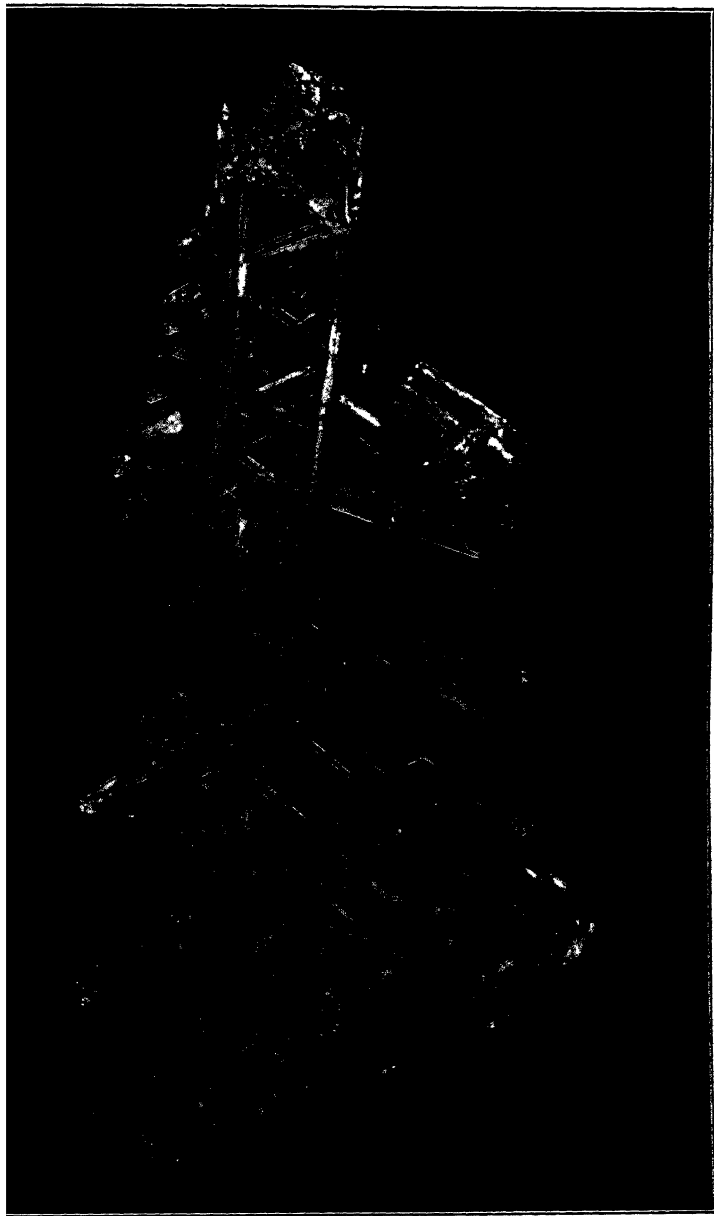
tion it assumes so many phases and is intermittently graded from one extreme to the other under so many links of condition that its complete illustration is almost impossible. Quartz is the oxide of silicon, it crystallizes in the hexagonal system, and for the most part presents in crystals six-sided prisms terminated by six-sided pyramids, which are, however, not made up of similar elements; three faces belong to one rhombohedron and three faces belong to a second, the positive rhombohedron usually predominating. Twins occur parallel to the vertical axis, which brings the faces of the two rhombohedrons of different crystals together (Fig. 353, s and r), the areas belonging to the different individuals being indicated by contrasted surfaces. Twinning, also symmetrical, brings the faces of the two rhombohedrons into coincidence (Fig. 354); this twinning prevails in amethyst, where the union of two crystals (one right-handed, the other left-handed) produce contrasted optical and electrical phenomena. Contact twins, as they are called, also occur (Fig. 356, 357), and many pseudo effects of twinning are found where crystals are crowded together in parallel lines. Massive varieties of quartz are familiar, as jasper, agates and chalcedony. Quartz replaces vegetable tissues, and splendid examples of silicified wood illustrate this completely. Quartz has for the most part been deposited from water solution, and this circumstance has given it a wide intermolecular diffusion, so that in cavities, in seams, crevices, between the fragments of stones and the interstices of mineral beds, this universal species is prevalent, varying from its crystalline form to massive, banded and cellular, and, taking up iron and other metallic oxides, becomes variegated in color, while the crushed and abraded detritus of quartz rocks forms the variously colored siliceous sands.

It would be impossible to indicate in the space of a guide the numerous interesting examples of quartz on exhibition in collections. In the larger examples occur magnificent groups from Magnet Cove, Ark.; large crystals from Switzerland, the curious cellular and irregular pyramid from the Tyrol, the fine expanse of crystals from Ellenville, N. Y., the handsome groups from Alexander Co., N. C., will challenge attention. The visitor will often notice the smoky quartzes from Switzerland, the spotted quartz from Guttenen, the singular pinhole cavities in the specimen from Dissentis, Switz., the "skeleton" surfaces from Grimsel, the tapering pyramids (produced by combinations of prism and rhombohedron) from Schemnitz, Hungary, the numerous amethysts, the ferruginous encrusted crystals from Silesia, cellular quartz from England, the rose-colored opaque short prisms from the Bay of Fundy, the drusy surfaces of low pyramids from Poo-
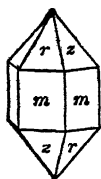
Fig. 346
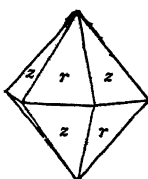
Fig. 347
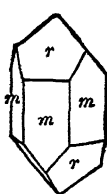
Fig. 348
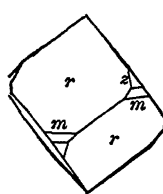
Fig. 349
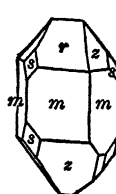
Fig. 350
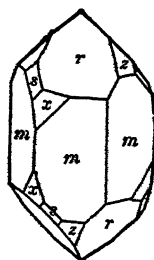
Fig. 351
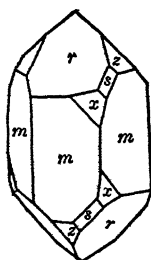
Fig. 352
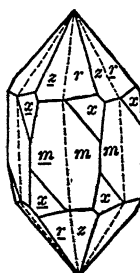
Fig. 353
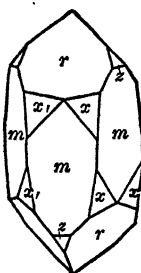
Fig. 354
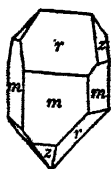
Fig. 355
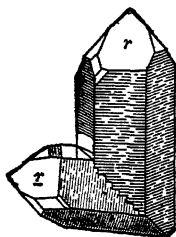
Fig. 356
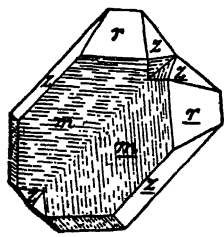
Fig. 357
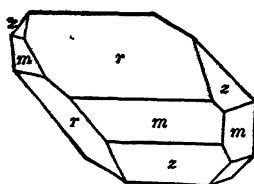
Fig. 358

PLATE 19

nah, India, the distorted crystals from Ellenville, N. Y., the various chlorite saturated specimens, the "quartzoids" (pyramids without, or almost without prisms) from Hermon, N. Y., crystals embedded

in calcite from Salisbury, N. Y., the capped crystals from Roxbury, Conn., and the large water inclusions in crystals from Hot Springs, Ark.

Quartz possesses some remarkable physical properties, polarized light is rotated, and the direction of rotation is either right or left-handed, the direction being indicated by the position or inclination of the trapezohedral faces on the prism, if present; (Fig. 352 is right-handed, Fig. 351 is left-handed). It is pyro-electric; on changing temperature a crystal is "divided into + and — electrical zones parallel to the alternate prismatic edges." Etching the faces of the pyramid reveals the differing character of the alternate planes, and also develops pittings, with their broader ends directed to the right or left as the crystal is right or left-handed.

Quartz forms pseudomorphs after Calcite, Glauberite, Gypsum, Wulfenite, Barite, Aragonite, Spodumene, Fluorite. From Hot Springs, Ark., there are occasional examples of a single pyramid, the second rhombohedron being almost suppressed; cellular quartzes are seen from the Tyrol and Hungary, tourmaline saturated crystals from Montana, pitted and opaque interrupted crystals from Colorado.

The vagaries, as they might be termed, of quartz crystallization are numerous, as larger crystals terminating slim, narrow prisms broad twisted surfaces of smoky quartz crystals; slim, tapering pyramids; eaten, pitted, filmed crystals, often enclosing clay; spirally twisted crystals, quartz holding white blades of tremolite, which if removed by decomposition leave long, pipe-like holes in the quartz.

A very unusual crystallographic feature in quartz is the basal plane, and planes resembling such a plane (possibly made by erosion) are found truncating the terminal pyramid of North Carolina quartzes. A form of silica called *tridymite*, is found in an andesite from Mexico and also in other igneous rocks. It occurs in plates intersecting each other in the volcanic rock of the Euganean Hills, Italy. Asmanite in meteorites is supposed to resemble it. The plates of tridymite may be twinned.

Opal, the hydrated oxide of silicon, is less hard than quartz, has a lower specific gravity, and the amount of water varies. The varieties of opal are exhibited in cases from the glassy, blistered surfaces of Hyalite to the more dense and opaque semi- and wood-opals. Tabasheer specimens are sometimes exhibited. It is referred to Opal and is found in the joints of bamboo in small lumps or nodules. This singular vegetable secretion is now regarded by the best authorities as nature's way of disposing of the silica taken up by the plant, in excess of that required for the

formation of the hard siliceous external surface of the stem. Like Hydrophane, it absorbs water with great energy and becomes almost transparent when placed in it. (Judd, *Nature,* Vol. xxxv.) The *Geyserites* from the Yellowstone Park are placed here.

Here among the opals the visitor finds the rosy-pink *quincite* from France, the irised blues from Australia, jelly-like masses from Mexico, the strange pseudo-morphs in radiating crystals from the White Cliffs, N. S. W., the flesh-red and milky porcellanous cleavage nodules from Queretaro, and the many precious opals whose iridescent and brilliant play of colors (presumably produced by cavities or films of different refractive indices) make this mineral a gem-stone. Closing the anhydrous oxides come *Senarmontite* in white octahedrons from Algeria; *Valentinite* in yellowish prisms from Pribram, Bohemia; *Cervantite* in hollow pipes from Borneo as altered Stibnite from Mexico; yellow *Molybdite,* red *Kermesite* Stibiconite and *Tungstite.*

Diaspore, the hydrated sesquioxide of aluminium, is developed in lavender purple blades or plates at Chester Mass, associated with *emery,* and in whitish-yellow sheets at Unionville, Pa. *Turgite,* in red and black detachable crusts or skins, looking very much like limonite is found in varnished surfaces at Salisbury Conn.; *Göthite* in brown acicular tufts, black exteriorly, from Michigan, in orthorhombic plates from Cornwall, England, in steely needles, sprinkled over barite, from Ilefeld Hartz, are seen in the hydrous oxides. *Beauxite,* the valuable ore from which Aluminum was and is extracted, is nodular, and has been found in valuable deposits in Georgia, Alabama, and Arkansas, and further north in Tennessee, Virginia, and Pennsylvania. Beauxite is also used for a refractory lining in furnaces.

Gibbsite in stalactitic, globular, mamillary concretions colored by iron oxide, comes from Richmond, Mass., but it was discovered as a crystallized (Monoclinic) mineral in schists at Zlatoust Ural Mt.

Uraninite, famous as the source of radium is a black mineral, a mixture of uranium oxides, pustulose and botryoidal usually, but a crystallizing compound occurring in octahedrons. It always contains lead, perhaps thorium, yttrium, lanthanum, cerium, and nitrogen. Bröggerite, Cleveite, and Nivenite are varying forms of it. *Gummite* is an alteration product of uraninite and quite commonly shown as an orange to yellow mass embedding a black nucleus of unaltered uraninite. Here may be placed *yttro* and *thoro gummite,* and chlorothorite.

Limonite, the hydrated sesquioxide of iron, is one of the most common forms of this earth, and assumes various and con-

CERUSITE (Twinned)
Broken Hill Mine, New South Wales
Bement Collection, American Museum of Natural History

PARISITE
Muso Valley, New Granada
Bement Collection, American Museum of Natural History

trasted appearances, from dull earthy aggregates to brilliant sheen-covered mammillated masses like the specimens from Salisbury, Ct., and Cleator Moor, Eng. Frequently collections contain an instructive series of examples of this species, which illustrate its water origin. This is shown in the concretionary layers by which its nodules and masses are built up, the irregular stems, spheres and stalactitic forms in which it occurs, and the localities where it is being constantly accumulated, as in the "mustard-seed" beds of Swedish lakes. Very excellent specimens, demonstrating its gradual deposition are often exhibited in stalactites from silver mines; its branching form and the concentric sheaths of mineral deposit, seen in cross section, are the self-evident indications of a gradual release from solution of the oxydized ferrous salts. The fibrous, terracotta films, with their blackish, varnishlike surfaces, from Salisbury, Conn., and Marquette, Mich. (often Turgite), are representative specimens, and the botryoidal, mammillated masses from Dover, Armenia, N. Y., and Marquette, Mich. Limonite by deoxydation through organic matter, with carbonic acid, becomes siderite, and by loss of water hematite. It is in all cases the result of the alteration of other ores or minerals containing iron.

Brucite is no longer a common species and the beautiful crystallizations at Texas, Lancaster Co., Pa., are somewhat rare. The plates are broad rhombohedrons, and crowded in spheres or grouped in diverging crests, form objects in their delicate and shaded tints of green of much beauty.

The visitor may be permitted to examine, where these precious species are present, the unique oxides and oxychlorides (with ammonium in *Kleinite*) of Mercury, found at Terlingua, Texas. They are most unusual. Montroydite is a carmine-red colored species in needles, Terlinguaite a yellow to olive green (depending on exposure to light) crust, Eglestonite yellow to brown (or black) crystals, Kleinite a yellow to orange substance. In the order here given they are orthorhombic, monoclinic, isometric and hexagonal in crystallization. They occur, along with mercury, calomel, and cinnabar in mineralized fault joints of cretaceous limestones.

SILICATES

The Silicates embrace the larger proportion of mineral species, and are the essential elements of most of the crystalline rocks. They are unions of basic elements (the oxides of the alkalies, alkaline bases and metals) with several types of silicic acid, the compound being considered a tri-, di-, uni- or sub-silicate, according

to the type of silicic acid which has formed it, or more exactly, according to the oxygen ratio of the bases and the acid (see below). The opinions of authors are somewhat at variance in their interpretation of this great group of natural compounds, and the part played in some of the species by water, as to whether it takes the part of a base or is to be regarded simply as water of hydration, as in clays, or of crystallization as in zeolites (Analcite, Apophyllite, Stilbite, etc.). These silicates are for the most part salts of potash, soda, lithia, lime, magnesia, alumina, chromia, and iron, with occasional admixtures of metallic bases and the rarer earths, as Ceria, Yttria, Didymia, Lanthania, and Boracic acid; also metallic silicates, as those of Zinc, Copper, Cerium, Nickel, Manganese. Two broad divisions in the silicates can at once be made, the Anhydrous and Hydrous Silicates, and these are again broken up into smaller groups, based upon similarity of their members in composition, crystallization and optical properties.

Thus the Feldspar Group is one based upon the following natural characters: "1, Crystallization in the monoclinic or triclinic systems, the crystals of the different species resembling each other closely in angle, in general habit, and method of twinning. 2, Cleavage in two similar directions, inclined at an angle of 90° or nearly 90°. 3, Hardness between 6 and 6.5. 4, Specific Gravity varying between 2.5 and 2.9, and mostly between 2.55 and 2.75. 5, Colors white or pale shades of yellow, red or green, less commonly dark. 6, In composition silicates of aluminium with either potassium, sodium or calcium, and rarely barium, while magnesium and iron are always absent." (Dana). The feldspar group is a well marked and compact collocation; other groups present similar resemblances as the Pyroxene and Amphibole Groups, the Garnet Group, the Sodalite Group, Scapolite Group and others. The separation into di-, uni- and sub-silicates is based upon the oxygen ratio (see Introduction) of the bases to the silica; thus Pyroxene, in the variety Diopside, is represented by $CaOMgOSiO_4$ when the two oxygen atoms of the bases are doubled in the oxygen atoms of the silica, or it is a disilicate. Similarly with Garnet (var Grossularite), $3CaOAl_2O_3SiO_6$, where the six oxygen atoms of the bases exactly equal the oxygen atoms of the silica, or it is a unisilicate, and an example of a subsilicate, which is a less fixed relation, is seen in Tourmaline, where the oxygen atoms of the silica are in general 2, to 3 oxygen atoms of the bases.

This view of the silicates has been somewhat modified recently and in new systems of mineral classification there has been invented a series of silicates known by the names of Disilicates,

Metasilicates, Orthosilicates, Subsilicates. These acids do not exist, they represent a convenient system of symbolism simply.

A chemical feature of the greatest importance in the constitution of Silicates is the replacing power of the bases, whereby basic molecules of equal combining power displace each other. For instance, the sesquioxide of alumina (Al_2O_3) can be replaced by the sesquioxide of iron (Fe_2O_3)—except in the feldspars—and so lime, magnesia, protoxide of iron, are substituted for each other, having an equal oxygen combining power, and these again can take the place of the oxides of potassium and sodium (K_2O Na_2O). This shifting power comes prominently into view in Garnet, where with an identical theoretical formula the composition of the different varieties is different through the action of this prevalent law. The general groups grade into each other to some extent and frequently display variant characters, as the micas, which give them a dual expression. But a few species can be separately treated in a limited space, such as this guide, and these species are selected with reference to their universality and their scientific features as reflecting upon the general subject of the Silicates.

ANHYDROUS SILICATES.
PYROXENE GROUP

Species.	System.	Composition.
Enstatite.	Orthorhombic.	Silicate of magnesia.
Hypersthene.	"	Silicate of iron & magnesia.
Wollastonite.	Monoclinic.	Silicate of lime.
Pyroxene.	"	Silicate of bases.
Acmite (Aegirite).	"	Silicate of soda and iron.
Rhodonite.	Triclinic.	Silicate of manganese.
Babingtonite.	"	Silicate of lime, iron and manganese.
Spodumene.	Monoclinic.	Silicate of alumina & lithia.
Petalite.	"	Silicate of alumina & lithia.

AMPHIBOLE GROUP

Amphibole.	Monoclinic.	Silicate of bases.
Arfvedsonite.	"	
Crocidolite.	"	Silicate of iron and soda.
Beryl.	Hexagonal.	Silicate of beryllia and alumina.
Eudialyte.	Isometric.	Silicate of soda, lime, iron, zirconia with chlorine.

CHRYSOLITE GROUP

Species.	System.	Composition.
Chrysolite.	Orthorhombic.	Silicate of iron & magnesia.
Forsterite.	"	Silicate of magnesia.
Monticellite.	"	Silicate of lime & magnesia.
Fayalite.	"	Silicate of iron.
Tephroite.	"	Silicàte of manganese.
Knebelite.	"	Silicate of manganese & iron.
Leucophanite.	"	Silicate of beryllia.
Wohlerite.	Monoclinic.	Contains zirconia and columbia.
Willemite.	Hexagonal.	Silicate of zinc.
Phenacite.	"	Silicate of beryllia.
Helvite.	Isometric.	Silicate of manganese, iron.
Eulytite.	"	Silicate of bismuth.
Danalite.	"	Silicate of iron, zinc, manganese, beryllia, with sulphur.
Meliphanite.	Tetragonal.	Silicate of soda, lime and beryllia, with fluorine.
Garnet.	Isometric.	Silicate of bases (many).
Zircon.	Tetragonal.	Silicate of zirconia.
Vesuvianite.	Tetragonal.	Silicate of lime, iron and alumina.
Melilite.		Silicate of soda, lime, magnesia, alumina and iron.
Epidote.	Monoclinic.	Silicate of lime, iron and alumina.
Allanite.	"	Silicate of bases.
Zoisite.	Orthorhombic.	Silicate of lime & alumina.
Gadolinite.	Monoclinic.	Silicate of iron, beryllia and yttria.
Mosandrite.	Orthorhombic?	
Ilvaite (ardennite).	"	Silicate of lime and iron.
∫ Axinite.	Triclinic.	Silicates with boron.
∫ Danburite.	"	Silicates of lime with boron.
Iolite.	Orthorhombic.	Silicates of magnesia, iron and alumina.

MICA GROUP

Phlogopite.	Monoclinic.	Silicate of magnesia, alumina, etc.
Biotite.	"	Silicate of potash, iron, alumina and magnesia.

STALACTITIC MALACHITE
Bisbee, Arizona
Bement Collection, American Museum of Natural History

Species.	System.	Composition.
Lepidomelane.	Monoclinic	Iron biotite.
Astrophyllite.	"	Titanium silicate of bases.
Muscovite.	"	Silicate of potash & alumina.
Lepidolite.	"	Silicate of potash, lithia and alumina with fluorine.
Cryophyllite.	"	As lepidolite.

WERNERITE GROUP

Sarcolite.	Tetragonal.	
Meionite.	"	Silicate of lime & alumina.
Wernerite.	Tetragonal.	Silicate of soda, lime and alumina.
Dipyre (mizzonite).	"	Silicate of soda, lime and alumina.
Nephelite.	Hexagonal.	Silicate of soda, potash and alumina.

LEUCITE GROUP

Sodalite.	Isometric.	Silicate of soda and alumina, and chloride of sodium.
Lapis Lazuli.	"	Silicate of soda, lime, iron, alumina with chlorine and sulphuric acid.
Hauynite.	"	Like sodalite.
Noselite.	"	Like sodalite.
Leucite.	"	Silicate of potash & alumina.
Pollucite.	"	Silicate of potash, soda, alumina and caesia.

FELDSPAR GROUP

Anorthite.	Triclinic.	Silicate of lime & alumina.
Labradorite.	"	Silicate of soda, lime and alumina.
Oligoclase.	"	Silicate of soda, lime and alumina.
Albite.	"	Silicate of soda & alumina.
Orthoclase. (microcline.)	Monoclinic.	Silicate of potash & alumina.
Chondrodite.	Orthorhombic.	Silicate of magnesia.
Tourmaline.	Hexagonal.	Silicate of bases.

ANDALUSITE GROUP

Species.	System.	Composition.
Andalusite.	Orthorhombic.	Silicate of alumina.
Fibrolite.	"	Silicate of alumina.
Cyanite.	Triclinic.	Silicate of alumina.
Dumortierite.	Orthorhombic.	Silicate of alumina.
Topaz.	"	Silicate of alumina.
Datolite.	Monoclinic.	Silicate of lime with boracic acid.
Titanite.	"	Silicate of lime with titanium.
Keilhauite.	"	Silicate of yttria, lime, iron, alumina, with titanium.
Staurolite.	Orthorhombic.	Silicate of iron, magnesia and alumina.
Schorlamite.		Silicate, lime, iron.
Isopyre.		
Hypochlorite.		

The pyroxene group of minerals embraces a series of blending chemical compounds quite contrasted in appearance, and crystallizing in different systems. It is an attractive section in the mineral cabinet, and in Spodumene furnishes two important gem stones, *Hiddenite,* and *Kunzite.* The gradual resolution of a number of earlier species into pyroxene and its associates arose as clearer ideas prevailed as to the wide variations in composition, of the mineral pyroxene, accompanied as it is with optical or physical differences. Of pyroxene itself *diopside* has been often chosen as typical, and it is a silicate of calcium and magnesium, in which by replacement, iron and aluminum may enter, and thus its mineral variations ensue.

Enstatite, in dark-green orthorhombic crystals (prisms, pyramids, and pinacoid) from Bamle, Norway, often altered into soap-stone, is seen in collections. The mineral was doubtfully established (from small crystals in meteorites), until these remarkable huge specimens from Norway turned up. It occurs also as *bronzite* in fibrous sheared masses, yellowish-brown and pearly in luster. It is found in St. Lawrence Co. N. Y.

Hypersthene is shown in unison with labradorite in anorthosite from Norway, in polished sections, and in minute glistening scales in trachyte from Transylvania.

Wollastonite, in fibrous, satiny masses from England, gray and crystallized from Natural Bridge N. Y. and in white terminated blades in volcanic rock from Mt. Somma follows, with peculiar

reddish forms presumably admixed with *rhodonite* from Franklin Furnace, N. J.

Pyroxene, a silicate of lime, magnesia and iron, with the presence, more or less occasionally, of alumina, manganese and zinc, typifies a group of related minerals which are similar in form. This similarity in form is defined by a fundamental prism of an angle of 93° or 87°, parallel to whose faces there is a more or less perfect cleavage in all the species. The crystalline resemblance is carried out further, and though the orthorhombic, monoclinic and triclinic systems are represented, their angles in certain zones in the species here grouped together are similar. Pyroxene undergoes a change to Amphibole, and one of the most familiar illustrations of *paramorphism* is the change of pyroxene with its rectangular cleavage and lamellar texture to amphibole with its oblique cleavage and granular or fibrous texture. The varieties of *Pyroxene* may be conveniently divided into the aluminous and non-aluminous grades, in which, also according to the law of substitution, already explained, the alkaline metallic or earthy oxides replace each other in varying proportions. There are included under the aluminous varieties, *Augite* and *Fassaite,* and under the non-aluminous, *Diopside* (malacolite), *Hedenbergite* (sahlite), *Diallage, Coccolite, Schefferite,* and *Jeffersonite.*

Pyroxene derived its name from an erroneous impression that it was not found in igneous rocks, the name meaning "a stranger to fire," whereas it is a common ingredient of igneous rocks and forms a large mineral percentage of the dolerites, gabbros and melaphyrs. Pyroxene varies from almost white (malacolite) through lighter shades of green to black, in augite; its oblique crystallization is well shown in examples from northern New York, where in the Adirondack region expressive groups of crystals made up of intersecting prisms, associated with orthoclase (loxoclase), are commonly found. Those from Diana, Lewis Co., are worthy of notice in any cabinet. The beautiful *diopside* with garnet from Piedmont, Italy, the manganiferous pyroxene (*Violan*) from St. Marcel, the *Augite* in scoria from Vesuvius, and the typical augite from Arendal, Norway, the white *Malacolite* from Dover, N. Y., showing basal cleavage, the *Jeffersonite* from Franklin, N. J., and the glazed coccolite grains in calcite from St. Lawrence Co., N. Y., illustrate some of the phases of this protean species. Hemihedrism in this monoclinic species has been demonstrated by Professors Williams and Penfield.

Acmite (*Aegirite*); this mineral and aegirite are respectively the stout and spear-shaped forms, black-green, found at Lan-

gesund fiord, Norway, and in splendid groups at Magnet Cove, Arkansas.

Rhodonite follows in superb and simple crystallizations, long prisms or tabular short crystals, from Franklin Furnace, N. J., developed in calcite. The red color shades into a dull or pale vermilion, and again brightens almost to a rosy tint, in the small crowded crystals from Paisberg, Sweden. It is a popular mineral, and its development in black streaked or veined masses in Russia furnishes an ornamental stone. *Bustamite* is a brown radiating variety.

Babingtonite is a green triclinic mineral, and, as a silicate of iron, is supposed to contribute, by intermixture, iron to rhodonite, in which iron and calcium reach considerable proportions.

Spodumene placed in the pyroxene series has considerable interest from the gem material Hiddenite, which surpasses in beauty the emerald, and which is a variety of this mineral, and also from the graded alteration products occurring in this notable species. This last process produces in one specimen a blended succession of parts, from the unaltered spodumene to a mixture and final separation of soda-feldspar and mica. Alteration products from Branchville, Conn., and Chesterfield, Mass., known as *cymatolite* and *aglaite,* upon microscopic study have been determined to be uniform mixtures of albite and muscovite.

Here occurs the delicate emerald green blades of hiddenite from Stony Point, N. C. taken in pockets, associated with pyrite, also the supremely fascinating lavender crystals of *Kunzite* from Pala California, which have formed a new gem of great beauty. The crystals are flat spear-shaped transparent sheets, rounded with wrinkled edges and of great size.

Petalite, a lithia mineral has been found in Maine in white colorless glassy masses, and in southern California, in association with the lithia bearing minerals of that prolific locality.

Amphibole, with its related species and the series of mineral variations included under this one name, forms a parallel section to pyroxene, containing, however, fewer species and less crystallographic variety. The prism in Amphibole is flattened, having an angle of $56°$ and $124°$, and in chemical constitution Amphibole, very generally, contains more magnesia and alkalies than pyroxene. The separation of its varieties under aluminous and non-aluminous groups obtains as in pyroxene. The aluminous section embraces *Edenite, Pargasite, Hornblende;* and the non-aluminous, *Tremolite, Actinolite* (nephrite, asbestus, smaragdite), *Cummingtonite, Dannemorite, Richterite,* most of which are rep-
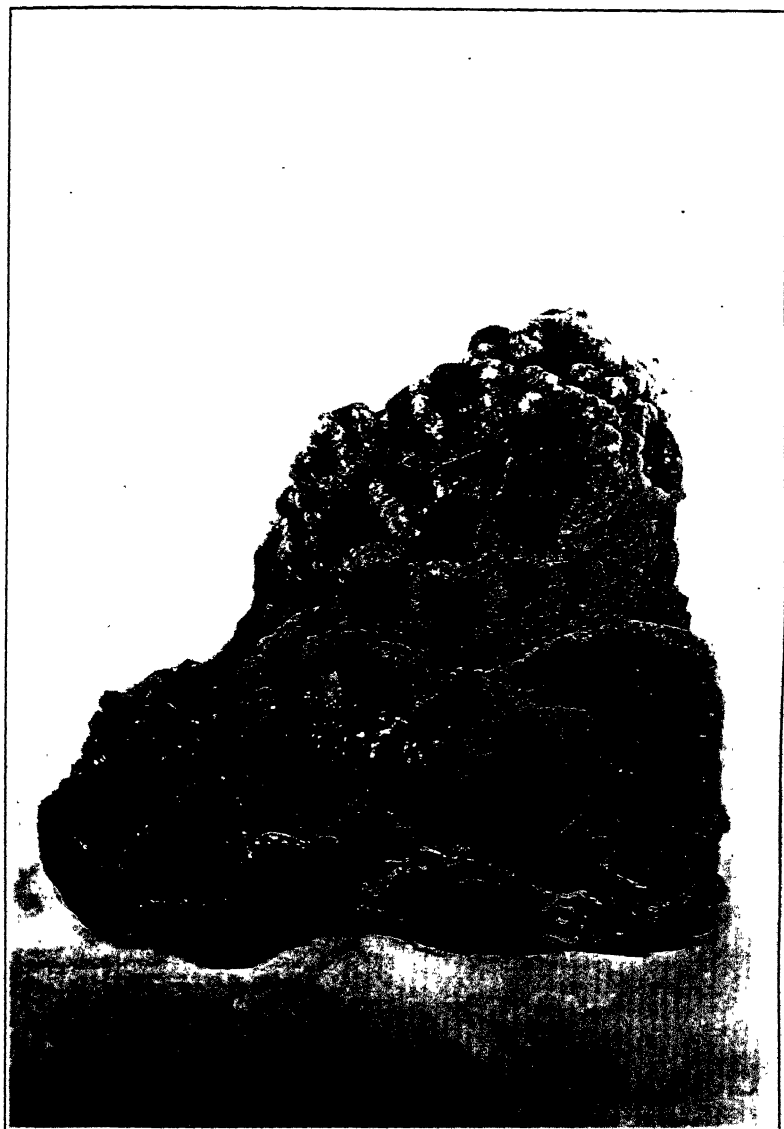
MALACHITE
Bisbee, Arizona
Bement Collection, American Museum of Natural History

resented by specimens in the cabinet. Amphibole, like Pyroxene, is a very widely distributed species and forms rock masses, entering into the composition of both metamorphic and igneous rocks, as well as local mineral crystallizations. Amphibole is subject to alteration, especially in the more fibrous varieties, and by taking up water, with a concentration of magnesia, becomes changed to talc, serpentine and chlorite.

Cabinets usually contain an instructive series of specimens, illustrating the very divergent lines of variation in external appearance which are developed in this species. Amongst these the peculiar woollike bundles of fibres of *Breislakite* from Vesuvius, Italy, the *Asbestus* from New York Island and the Tyrol, the woven, feltlike plates and masses of *Mountain Leather,* the radiating centers of *Hydrous Anthophyllite,* the mossy surfaces of *Byssolite* (St. Gothard, Switzerland), the blades of Tremolite developed in limestone, and the numerous hornblende crystals are especially interesting. *Crocidolite* (Tigers' Eye of jewelers) is, in its natural specific condition, a soft, fibrous, bluish mineral, which occurs in quartz schists in South Africa; infiltration of silica and an oxidation of the protosalts of iron converts it into the jewelers gem, so valued for its old gold color, its changing luster, its hardness and blended tints. Examples of the unaltered and silicified mineral are often on exhibition. Nephrite or Jade, so common in prehistoric carvings, is an Amphibole. Jadeite a very valuable and refractory apple-green to white stone is an aluminous silicate more fusible than nephrite.

Arfvedsonite is a soda amphibole found in black crystals, *glaucophane* a blue mineral forming schists, and developed in the coast ranges of California, *riebeckite* an iron, soda, aluminum silicate, perhaps plentifully distributed in schists and granite, related to glaucophane, through *crossite,* and an amphibole.

Beryl, the silicate of beryllium, forms a very distinct and conspicuous mineral species, its definite crystallization (hexagonal prismatic), its hardness, beauty, and range of color, contribute to make it a popular and important species. Beryl crystallizes in six-sided prisms, terminated with a flat basal plane; or in low summits made up of numerous pyramidal faces (North Carolina), or more rarely in high acute pyramids, which are twelve-sided (Colorado). The Emerald is a beryl containing chromium; alkalies and water also replace beryllium in beryl, and clay and mica may result as products of its alteration. Enormous beryls have been found in New Hampshire and Massachusetts, one of which, from Grafton, weighs nearly 3,000 pounds.

Beryl is common in granite veins and appears to have been amongst the first of the mineral ingredients of the vein to have crystallized, being surrounded and embedded in quartz, mica and feldspar. Large crystals from Acworth, N. H., are often exhibited, together with interesting examples enclosed in brecciated quartz, from New Milford, Conn.; some beautiful intergrowths of beryl and smoky quartz from Siberia, and emeralds in a bituminous limestone from Bogota, S. A., may be found in collections, together with many other specimens, amongst which the delicate aquamarines, valued by the ancients, appear. Long emerald crystals have been found in North Carolina, and gem crystals were washed out in ploughed land in Cleveland Co.

Pink beryls from southern California, of a peculiar crystal habit, and associated with tourmaline; pale sea-weed green crystals from Topsham, Me.; opaque faintly pink-white crystals in granite from Haddam's Neck, Conn.; curved green crystals from Rabenstein, Bavaria; tapering yellow translucent needles from Siberia, Siberian emerald crystals enfolded in gray mica; illustrate this favorite gem stone. The crystals of beryl are often broken across and the fractures filled in with quartz.

At Sugar Hill, Stoneham, Me. fine aquamarines have been taken, the 133 karat gems from one of these being now at the Field Museum of Natural History in Chicago. The beryl occurs embedded in the vein rock (pegmatite), and cannot often be separated without breaking. Golden beryls have been found at or near Stoneham Me., and pale pink beryls (caesium variety), and these latter have been taken elsewhere in Maine the finest stones yielding gems of high brilliancy, retailing at from $5 to $20 a karat.

Oxford Co. Maine has been characterized by a development of mineral treasures, Beryllonite, associated with apatite, beryl, cassiterite, columbite, and triplite, occurs in western Stoneham, and at Herndon Hill the finest yellow topazes, taken in the United States, have been found, with apatite, beryl, clevelandite (albite), columbite, fluorite, montmorillonite, triplite, herderite, bertrandite, hamlinite.

Eudialyte, in brown, red, isometric, crowded crystals, comes from Greenland and Magnet Cove, Arkansas.

Chrysolite, the silicate of iron and magnesium, is of common occurrence in eruptive rocks where it is found in disseminated grains or in large nodular masses (bombs), as at Vesuvius, in the igneous rocks of the Auvergne region in France, and very strikingly in the doleritic boulders from Thetford, Vt. Its characteristic color is green, which becomes tarnished by the oxidation of the iron, while in the case of the removal of the latter, it forms

serpentine, a hydrous magnesia silicate, and this latter alteration has often taken place over large areas. It is found extensively in meteorites scattered in nests in the iron mass. When of gem quality it forms the gem *Peridot,* admired for its delicate olive transparency.

Peridot in gem quality has been derived from the east—the Levant—and may have been introduced into Europe at the time of the Crusades. The exact locality whence it came has recently had some light thrown on it from the occurrence of this mineral on the Red Sea in Africa. The ant-hills of the Navajo Reservation in Arizona have furnished small useful stones, found in connection, at the same place, with rich-colored garnets. Chrysolite or olivine alters readily to serpentine.

The chrysolite minerals *forsterite* (yellow crystals, small, in Mt. Somma lava), *monticellite* (rare, yellow, Mt. Vesuvius), *fayalite,* (iron silicate in tabular xtals in slags), *tephroite* (gray liver-colored, massive from Franklin, N. J.), *knebelite,* (gray, massive), *leucophanite,* (greenish white sphenoidal in crystals, phosphorescent, heated or struck), follow in old classifications, though now a little scattered in different groups.

Wöhlerite is a honey yellow mineral from Brevik and Barkevik, Norway, containing niobium near which in recent collections are seen the rare *Rosenbushite* and *Lavenite.*

Willemite is of interest as a metallic silicate, being the silicate of zinc. Its hexagonal form in many examples exhibited, with rhombohedral terminations, is easily recognized. In New Jersey it constitutes an important ore of zinc and at Franklin and Stirling Hill is found massive in ore bodies, parti-colored through the intermixture zincite, franklinite and *willemite.* The canary yellow willemite is rare, and when of good quality and adequate density may be cut into gem stones. The better crystallized specimens of willemite are usually contaminated with manganese, when they assume a flesh-color tint and are known as *Troostite.*

This mineral in some phases is very sensitive to radium emanations. In the dark, upon exposure to radium, it softly glows with a rich yellow green light. Delicate green colors are said to fade in the light.

Phenacite is a mineral of some rarity and derives its name—a deceiver—from its resemblance to quartz in its crystallization, for which species it was on this account mistaken. Beautiful crystals of this species have been found at Mt. Antero, Colo., where it is associated with quartz, bertrandite and beryl, from which latter mineral it was probably derived. Examples from Mt. Antero

and specimens from France are exhibited. Wonderful crystallizations have lately come from Brazil.

Helvite, Eulytite, Zunyite are interesting tetrahedral minerals, yellow to brown-red in color; *eulytite* twinned; *zunyite* associated with lead ores which form, in part, a lead sulphate in which the glassy zunyite crystals are imbedded. *Danalite,* dark red-brown in octahedrons and rhombic-dodecahedrons, *meliphanite,* honey yellow plates from Norway are less conspicuous.

Garnet, a variable silicate of lime, magnesia, iron and alumina, with coloring admixtures of chromium and manganese is one of the most familiar and commonly collected minerals. Its common form is well known and it is so common in schists, gneisses, granites, eruptives and limestones as to give it a prominent position in cabinets. Its crystalline form (Figs. 359, 364) is isometric; but, although it should exhibit no double refraction, in some anomalous cases it does, and this has led to an attempted reference of its crystals to the "complex twinning of triclinic individuals." A singular difference in this way in the optical properties of garnets has been pointed out, between those formed in igneous masses or in rocks changed by metamorphism, over wide areas, and
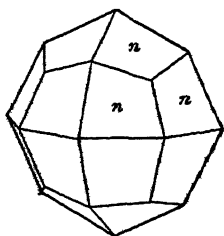
Fig. 359
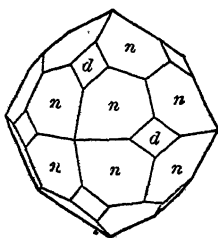
Fig. 360
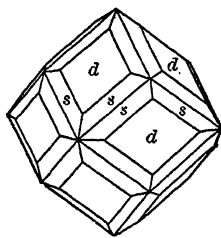
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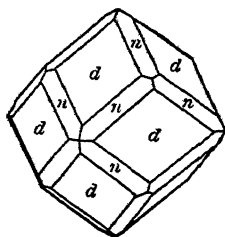
Fig. 362

Fig. 363

Fig. 364

PLATE 20
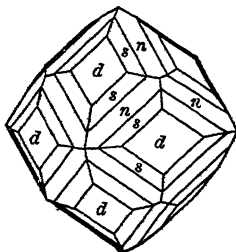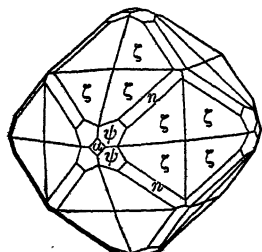
VELVETY MALACHITE
Bisbee, Arizona
American Museum of Natural History

those formed in crevices which have been filled by crystallization from hot solutions or in limestones which have been altered by contact with igneous rocks. The former are without double refraction and the latter exhibit it.

The garnets are separated into six varieties, each of which are distinguished by composition and, to some extent, by color. They are:

> Grossularite, lime alumina garnet.
> Pyrope, magnesia alumina garnet.
> Almandite, iron alumina garnet.
> Spessartite, manganese alumina garnet.
> Andradite, iron lime garnet.
> Ouvarovite, chromium lime garnet.

Examples of all of these varieties are exhibited in collections. The garnet forms in its more beautiful phases a rich and desirable gem, but is most frequently penetrated by flaws and often includes foreign material or even becomes reduced to a thin shell enclosing a different mineral nucleus. Garnet is a capital illustration of the "law of substitution," where alumina, iron, chromium and manganese, lime and magnesia, replace each other in the garnet so as to produce the different varieties. It is subject to change, and one of these changes, shown in the Salida, Colorado, garnets, affects a replacement by chlorite of the outer surface of the garnet, while in garnets from Lake Superior (same section) the chlorite frequently assumes the entire crystal. The process as explained by Penfield and Sperry is this: an oxidation of the iron, a decrease of silica, disappearance of manganese and lime, and an increase in magnesia, alkalies and water. Garnet also changes to serpentine and steatite.

In collections the visitor will notice the interesting amethystine garnets in mica schist from Alaska, the green garnets (Ouvarovite) from Siberia and Canada, the distorted crystals from Knauertown, Pa., the sparkling groups from Piedmont Italy, the striking developments in mica, with staurolite, from Roxbury, Conn., the flattened crystals in chlorite from Bethel, Vt. An instructive example of garnets distributed through mica schist is often exhibited with some large individuals from North Carolina. Richmond, Mass., furnishes superb dark crystallized specimens. Garnets of some beauty were found on New York Island by Mr. G. S. Stanton some years ago, and perhaps one of the largest of American garnets came from the Fourth Avenue excavations, and is now in the cabinet of Mr. G. F. Kunz.

The beautiful demantoid garnets (green) from Siberia figure extensively to-day in decorative jewelry.

Zircon, the silicate of zirconia, is the mineral substance which forms the gem *Hyacinth,* but usually as found in nature, fails to display gem qualities. It is opaque, coarse, dark-colored and fractured. Its well marked tetragonal crystallization, shown in the specimens on exhibition, in its four-sided prisms and terminal pyramids give it a distinct character. Notice the remarkable zircons from Renfrew Co., Canada, the opaque individual crystals from Buncombe Co., N. C., and the hyacinthine short crystals from El Paso Co., Colo.

Twinning in zircon was discovered by W. E. Hidden in specimens from Renfrew Co., Can., and Henderson Co., N. C. Zircon belongs to eruptive rocks and has crystallized out early, while prevalent also in schists and metamorphic rocks. It forms much of the sand in auriferous and gem dirt. Color can be discharged by heating, is variously colored yellow, brown, green, gray, red. Twinning habit is simple, forming stovepipe elbows or crosses; is regarded as isomorphous with cassiterite and rutile.

Vesuvianite (Idocrase) is so named from its occurrence at Mt. Vesuvius, Italy, in the ejected blocks on the outer volcanic rim, known as Mt. Somma. It is also a tetragonal mineral, crystallizing in four-sided prisms with pyramidal terminations, usually developed on the sides of basal planes, a true apex being rarely found. A massive compact form from California is called *Californite* (Kunz). Found well developed in the Urals, at Ala, Piedmont, Monzoni Tyrol, Norway, Siberia, and in low pyramids with prism at Magnet Cove, Arkansas, in pitted yellow green large crystals; weathered out in a stream-bed.

Mellilite, a vesuvian mineral, in square prisms, sometimes twinned, yellow to brown and whitish gray (*humboldtilite, zurlite*) is inconspicuous. To-day its ordinal position is quite changed, being near Wernerite.

Epidote is remarkable for its pleochroism, showing green, brown and yellow colors, according to the position it is held in, viz, rays parallel to a prismatic face are green, to a pyramidal face are brown, to a pinacoid yellow. The exquisite groups from Knappenwald, Untersulzbach, Pinzgau, Tyrol, present these variations of color well. The collections contain an interesting series of these beautiful crystals combined in numerous ways and elegantly facetted with terminal planes. Epidote occurs in small encrusting crystals upon feldspar on New York Island, and examples present these minerals together, enhancing each other by their accordant tints, the pink of the orthoclase and the green of the epidote.

Very important crystals (twinned) of a dark green, and in stout trunk-shaped forms, have been received from Alaska. They are prominent in cabinets.

Allanite, chemically formed like epidote and showing a sympathetic crystallization, contains a very different group of elements, embracing in some instances besides silica, alumina, iron, lime, magnesia, manganese and alkalies, the rarer ingredients of cerium, didymium, lanthanum, yttrium and erbium. It is also pleochroic. It has a local interest as occurring with some frequency on New York Island, where in granite it appears as long prismatic crystals, called *Orthite,* meaning straight. Examples from New York Island and the characteristic tabular crystals from Monroe, N. Y., are exhibited in collections, as well as the massive specimens from Virginia, Greenland, and Norway. The Norway crystals are especially striking and well developed from Arendal. Found in large plates in the Adirondack region.

Zoisite is found in green to brown blades from Ducktown, Tennessee, in delicate small rosy crystals from Piedmont Italy; in peach blossom pinks from Norway in polished slabs, wherein the color is due to manganese, and the mineral is associated with fluorite, garnet, epidote, and idocrase. It occurs in gray crystals in southern California.

Gadolinite in stout crystals from Hitterö, Norway, in a granite, from Ytterby, Sweden, and in red coated nodular masses from Llano Co. Texas; *Ilvaite* in obliquely terminated dark to black crystals from Elba, the Harz, Silesia, Tuscany, Norway, succeed. The crystals of the latter show perfect summits of pyramids and domes; the Harz specimens are deep black, sprinkled effectively in white quartz, the Lk. Baikal specimens are in squarish prisms curved, cracked, scaly in sandstone.

Axinite, from color and its triclinic habit, is an interesting and beautiful mineral, and examples from Dauphiny, France, and Dissentis, Switz., are good illustrations of its occurrence and grouping. It occurs yellow with red rhodonite at Franklin, N. J.

Danburite, now placed near topaz, which it resembles in crystallization, was seldom found in crystals of satisfactory finish until its remarkable development at Russell, St. Lawrence Co., was discovered. Crystals from this famous locality are always exhibited showing the basal plane, domes and various orders of prism.

Iolite, in black, stout crystals from Bodenmais, Bavaria, from Finland in blue masses, and from Kragerö Norway, and in blocks from Haddam Connecticut, precedes the micas in the old arrangements though now preceding garnet. This mineral, called

dichroite offers the familiar demonstration of dichroism or the varying color of the translucent crystals seen in different axial directions.

THE MICAS

The micas embrace a remarkable group of silicates, all of which are sharply distinguished by their laminated character, easily separating into sheets of the utmost thinness, these sheets being parallel to the basel plane. They crystallize in the monoclinic system and are for the most part silicates of alumina, lime, magnesia, iron and potash, with rare admixtures of other bases, as lithia in *lepidolite;* they contain water and graduate into the hydrous minerals of a similar physical constitution, the *chlorites,* etc.; alteration in them takes place by an assumption of water and the loss of potash, and change of the protoxide of iron to the sesquioxide also brings about a loss of luster, elasticity and transparency. The micas are very generally distributed through nature, forming rock masses in the schists and are an almost inseparable element in the granites and gneisses. They occur as well in igneous and metamorphic rocks and their minute scales derived from the decomposition of granitic rocks, are seen in the common sands. An explanation of the composition of the micas has been suggested by regarding them as mixtures of certain theoretical formulas of silicates. This has been worked out with some ingenuity though probably with little truth, Prof. Clarke's assumption of a single hypothetical molecule, being more simple. In this single molecule $[Al_4 (SiO_4)_3]$ replacement of the alumina by other bases furnishes the derivative micas.

Phlogopite, represented by a number of attractive specimens in collections, is a magnesia mica with a peculiar bronzy reflection. It loses transparency by taking up water. One peculiarity of mica is the display of six or twelve-rayed stars within its films when a single point of light is looked at through them. This phenomenon of diffraction is caused by the inclusion of crystals of rutile(?), which are microscopic, but serve the purpose of splitting the ray of light into rays at right angles to themselves. Crystals from St. Lawrence Co., N. Y., and Canada, are capital examples of mica crystals, found also at Franklin Furnace N. J.

Muscovite, a silicate of potash and alumina, is the common form of mica and occurs as finely disseminated scales or in broad sheets, which are used industrially. It is the micaceous constituent of granite, and when mined for commercial purposes is found
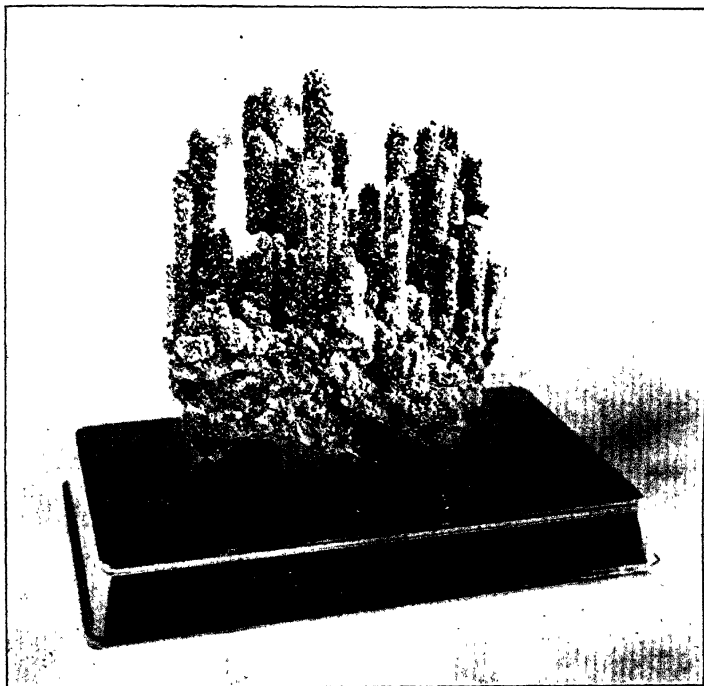
STALACTITIC AZURITE
Bisbee, Arizona
Bement Collection, American Museum of Natural History

in coarse granitic veins almost separated from the associated elements of quartz and feldspar. Intersecting crystals, curved spheroidal groups from Maine and Branchville, Conn., rose mica from Goshen, Mass., chrome mica from Italy and the Tyrol, and large sheets from Pennsylvania and New York, are amongst the many specimens illustrating this mineral. In Muscovite occur between the thin sheets, numerous inclusions known as "magnetic markings," which are for the most part lines or zones of iron crystallizations, which take on an alignment parallel to the crystalline faces of the mineral. The lines of increase of the crystals are often shown in sheets, appearing as phantom rulings in the transparent film. An instructive phase of alteration is shown in specimens from Auburn, Maine, wherein the edge has become pink from the change of the muscovite to lepidolite, and the removal of potash and the substitution of lithia. Muscovite crystals viewed perpendicular to the base are opaque, while at right angles to the prism the crystal is entirely translucent. Examples from Bakersville, Mitchell Co., N. C., exhibit this dichroism completely. A great number of alteration products placed under the Margarophyllites are the results of the hydration of muscovite accompanied by the insertion of other bases, as lime, magnesia, etc. Some of the many intergraded Margarophyllites are now placed under mica, though they have originated from very different minerals; but as they approximate in composition and especially have the characteristic physical constitution of mica, this seems a natural assignment.

Biotite, or black mica, is a magnesian silicate with alumina, iron and potash, and is of interest as occurring in beautiful nests of crystals in the ejected blocks of Mt. Somma, Vesuvius, Italy, where slightly greenish and quite translucent, it appears in splendent plates as a very pretty mineral object. It is distinguished from Muscovite in this particular, as the latter is far more rarely an ingredient in volcanic rocks. Biotite occurs intercrystallized with muscovite, and specimens from Portland, Conn., often show this peculiar intergrowth. The two micas are arranged generally symmetrically in relation to their prismatic planes. In examining a series of sections from one specimen, it is found that the proportion of the two micas varies in different parts of the crystal; the biotite, the least stable, giving way to the more stable muscovite. (H. Carvill Lewis.)

Lepidolite, the lithia mica, with its varieties, *Zinnwaldite, Cryophyllite, Astrophyllite,* the beautiful golden bladed mica from Colorado, now regarded as a titanate, further illustrate the mica

habit. They will generally be found near the micas in the same case.

Wernerite (Scapolite), which succeeds the micas with its related species, *Meionite, Sarcolite,* and *Dipyre* (Mizzonite), is readily recognized by its four-sided (tetragonal) crystallization and simple pyramids; its varieties in color are well illustrated and some of its alteration products presented. Wernerite is subject to change, and by water and carbonic acid, with substitution of potash, iron and magnesia, is converted into a mica, epidote and steatite.

Leucite is the type of a group of related species which crystallize in the isometric system. The trapezohedral form of Leucite is well shown in the specimens from Vesuvius, also their intersections and confused groupings. Leucite is typical of recent volcanic rocks. It possesses abnormal double-refraction and has been referred to the tetragonal and orthorhombic systems on this account, but this peculiar double-refraction (the isometric system should be without it) disappears upon heating to 500°.

Sodalite, Lapis Lazuli (Lazurite), **Hauynite, Noselite,** are isometric minerals, blue in color and chemically distinguished by the ingredient of soda and their resemblance to garnet. Examples show their characteristic appearance.

Nephelite is attractively displayed in the volcanic blocks of Mt. Somma, and its short, glassy, six-sided prisms, under a low magnifying power, reveal their hexagonal symmetry perfectly. The massive nephelite (elaeolite) is represented in specimens from Norway and Arkansas.

Mica of very pure non-ferriferous properties is now much desired in electrical insulation, and the industry has some importance in the United States. The abjectly cheap labor of India reduces the price of the Indian product. In 1909 the United States produced 1,809,582 pounds, in the sheet, valued at $235,000.

THE FELDSPARS

The feldspars are a natural group of minerals similar in constitution, properties and form. They are amongst the most widely disseminated silicates, and in metamorphic and volcanic rocks equally obtain a persistent representation. Their general characters have already been given (p. 152). They are divided into monoclinic and triclinic feldspars, the former embracing the potash feldspar othoclase, with a soda and baryta feldspar (Hyalophane), and the latter the triclinic feldspars, Albite, soda feldspar; Labradorite, Oligoclase, and Anorthite, lime feldspar.

Microcline, a variety of orthoclase but regarded as triclinic, with *anorthoclase,* forms a subsection more closely allied to the monoclinic orthoclase than the triclinic species, and the triclinic members grade somewhat into each other. The feldspars exhibit especially the triclinic forms, under the microscope and frequently to the naked eye fine striations, which appear over the surface of the mineral like straight rulings. These are indications of what is called polysynthetic twinning, a series of thin lamellae whose contiguous edges form minute but very straight lines. Twinning itself is a common feature in the feldspars, and so prevalent in certain crystallographic relations as to lead to the designation of certain types of twinning by names taken from the localities where these types abound. (See Orthoclase.)

Labradorite is famous for its beautiful chatoyant play of colors, which specimens in collections well display. The blue color has been regarded as due to polarization, from reflection from fine lamellae, while the red, golden and other tints proceed from minute acicular inclusions.
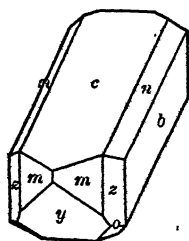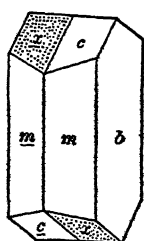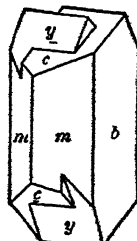
Fig. 365   Fig. 366   Fig. 367   Fig. 368
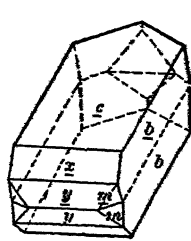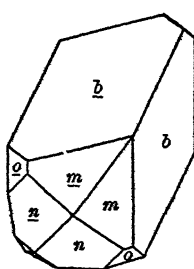
Fig. 369   Fig. 370   Fig. 371
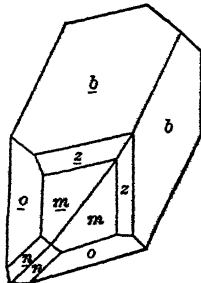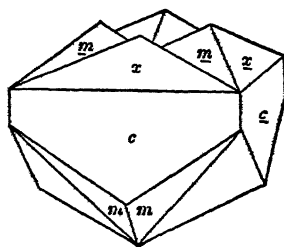
PLATE 21

Oligoclase is the mother species of the variety Sunstone, whose fiery reflections are highly prized. Excellent examples are shown in specimens from Norway. The brilliant schillerization is supposed to arise from numerous included crystals or grains of hematite or gothite. The peculiar glassy oligoclase from Mitchell Co., N. C., is worthy of notice from its eccentric expression. It was naturally regarded as beryl by good collectors until its real nature was detected by G. F. Kunz.

Albite is often represented by the very beautiful examples from Switzerland and the Tyrol, the cleavable masses from Groton, N. H., and the large crystals from Amelia Court House, Va. Twinning in the species is repeatedly shown and the elongated crystals called *pericline* are shown in the specimens from the Tyrol.

Orthoclase is always extendedly illustrated, and the three types of twinning are fully exemplified; the *Baveno* twin (Figs. 369, 370) from Baveno, Italy; the Manebach twin (Fig. 368) from St. Gothard's, Italy, and the Carlsbad twin (Figs. 366, 367) from Bohemia and Colorado. The green Amazonstones, so named from the Amazon River, where they were found abundantly in the last century, are now placed under the designation *Microcline,* and are separated from Orthoclase on the ground of a slight variation (30′) in the angle between the cleavage face (parallel to the base) and the vertical lateral face, this deviation making it triclinic. Excellent examples of this species are always shown. Specimens are to be noted where the green coloration is marked in patches, extending to a limital line within the border of the crystal. Other than this slight variation in angle the microcline species is identical with orthoclase. Magnificent specimens have been obtained from Pike's Peak, Colorado, and its frequent association with albite is noticeable, the albite crystals being implanted over it in roof-shaped flat plates.

Tourmaline is a species of interest and beauty; its well marked crystalline form, its contrasted terminations at opposite ends of the crystal, its variety and disposition of color, and its electrical properties, developed either by friction or heat, give it a prominent mineralogical position. The crystals have a characteristic three-sided appearance, from the development of the trigonal prism, and are much rounded by vertical striations; the rhombohedral terminations are also conspicuous. Many beautiful shades of color are seen in tourmaline, and the singular combination of the red cores and green coating from Brazil, the delicate pink crystals from Elba and their association with quartz, the black prisms from Norway and New York, the rich brown specimens

ORTHOCLASE
Amelia Court House, Va.
Bement Collection, American Museum of Natural History

WITHERITE
Northumberland, Eng.
Bement Collection, American Museum of Natural History

from Gouverneur, N. Y., the flat black prisms in mica and the blue (indicolite) from Goshen, Mass., are examples of its diversified appearance. The peculiar curved prisms from Yancy Co., N. C., the radiated specimens from Warwick, Mass., Oxford, Warren and Lynn, N. H., are interesting examples of its less frequent occurrence. Strong groups of radiating black crystals from New York Island are of interest, and the large single crystals in quartz, while the fine stout prisms in the Chamberlain collection of the New York Mineralogical Club at the American Museum of Natural History are of unique beauty. Tourmaline occurs in granites, gneisses, schists and limestone, and is frequently developed in the vicinity of eruptive rocks. Four varieties of tourmaline have been established upon color and chemical composition:

Alkali tourmaline, containing soda, potash or lithia; colors, green, red and colorless.

Iron tourmaline, containing iron; color, black.

Magnesian tourmaline, containing magnesia; colors, yellow, brown, black.

Chromium tourmaline, containing chromium; color, dark green.

The tourmalines attain a wonderful development in recent collections. In well furnished cabinets the visitor will notice the large, splendidly red crystals from California, the groups of projecting prisms sprouting from the rock like strong growths of asparagus stems, of delicate spinel-pink, grading into green bases; and also dark crystals with light summits, from Elba; the marvellous Haddam crystals, long green prisms and some just showing a blush of color at one end. The transparency of these and their melting tones are very beautiful. These Haddam crystals are often attached deeply by their acute edges to quartz, like a hatchet driven into wood, many are undulating and irregular.

An exquisite suite of these were presented to the American Museum of Natural History by J. Pierpont Morgan, though in many instances these are surpassed by examples in the Bement Collection.

A recent admirable bulletin of the U. S. Geol. Surv. on the Geology of the Pegmatites and Associated Rocks of Maine by Edson S. Bastin contains some interesting notes on the tourmalines of Mt. Mica. Black tourmaline occurs here a foot in length and 4 to 5 inches in diameter; some are recorded as 2½ to 4 (one) feet in length. The gem tourmalines vary greatly in form size and color. They invariably occur in pockets usually detached and lying "at the bottom in a sandlike matrix of kaolin and cookeite." They range in color from olive-green through emerald-green to blue-

green. "Some are nearly colorless, some show beautiful pink tints, and the central portions of some are a deep ruby-red when viewed along the main crystal axis; a few are the color of amber and of port wine; and some are a purplish-red. Many show a zonal distribution of colors. A polished cross section of a crystal about three-fourths of an inch in diameter, preserved in the Cambridge Museum of Natural History shows a blue-green center about one-half inch across, surrounded by a transparent pink border one-eighth inch wide, outside of which is a transparent olive-green border about one-sixteenth inch wide. Some single crystals shade from white at one termination to emerald-green, then to light green and pink, and finally to colorless at the other termination. Green crystals tipped with pink are especially common. Generally these transitions of color are very gradual, but in some specimens the colors are not mingled in the least, and the crystals, though crystallographically continuous throughout, seem to be composed of several distinct sections."

The tourmalines in some pockets crumble away as soon as touched; in others the surfaces may be brushed off and a beautiful gemmy nucleus left. In instances the tourmaline crystal has quite vanished through disintegration or solution, and their impressions in the clay alone remain. The largest tourmaline was $15\frac{1}{2}$ inches long, 7 inches breadth, weighing $31\frac{1}{2}$ pounds and valued at $400; green, pink, colorless. A white tourmaline (*achroite*) from this locality is transparent but viewed at right angles to its axis appears smoky, viewed in the axis, crimson. The largest gem cut from Mt. Mica tourmaline weighed $69\frac{1}{4}$ karats, bottle-green.

ANDALUSITE GROUP

These are mainly silicates of alumina, distinguished by hardness, orthorhombic symmetry, considerable development in metamorphic rocks, graduating into rock masses, and in Topaz forming beautiful crystallizations of gem consistency and color. The examples of Andalusite embrace the peculiar cross-shaped *Chiastolites,* wherein by a symmetrical replacement of the andalusite, the latter assumes the shape of flesh-colored stauriform centers, which are progressively changed in outline from one end to the other end of the crystals, and which are shown in various sections made at different points of the crystal's length. The topaz specimens are shown in greater perfection in the gem examples, but fine slabs from Mexico, sprinkled over with tapering crystals, illustrate unusual forms, while the more blunt and modified summits of the Colorado crystals and the massive specimens from

Stoneham, Maine, and Trumbull, Conn., are more ordinary. To-paz changes to kaolin and damourite, and the pure topaz is some-times surrounded by different colored layers (green, purple), which seem to be stages in a progressive alteration.

In collections the superb blue specimens from the Urals, the gem clear examples from Siberia, the Colorado specimens, mi-nutely pitted and streaked, with their modified summits, will be noticed; also the Brazilian yellow prisms and low pyramids, the numerous Mexican groups of intersecting crystals.

Datolite is a beautiful mineral which was found in great perfection in the tunnel excavated through the Palisade trap at Weehawken, N. J., in 1873 and the following years. It occurs thickly implanted in monoclinic crystals on trap, generally form-ing the first layer of secondary minerals in immediate apposition to the trap, while associated minerals subsequent in formation, as calcite, analcite, etc., cover its surface. It has been formed in crevices of the decomposing trap. (See below, Zeolites.) The examples from Paterson are noticeably large and stout.

Titanite, now placed in a section of titanates or titano silicates with Astrophyllite, etc., which remains, in old collections, with the micas, is a silicate of titanium and lime, and is remarkably varied in its crystalline forms. Its color, when a yellow-green, has invited the connoisseur to cut it into gem forms, but it cannot be considered a gem stone of permanent value. Good examples of the yellow, green, brown and gray varieties with twinned crys-tals are often exhibited.

Staurolite has a popular interest from the peculiar inter-secting groups, which in many instances form rectangular crosses (Figs. 372-379) and in other cases intersect at inclinations of 60°.

Chondrodite is a mineral, wonderfully developed at Tilly Foster, Westchester Co., N. Y., where the rich brown crystals, associated with magnetite, ripidolite, serpentine, (into which it al-ters), make very interesting groups. This mineral recalls Prof. Penfield's comparison of the three minerals chondrodite, humite and clinohumite (the last two from Vesuvius, Mt. Somma) whose ver-tical axes increase in the above order as a molecule of Mg_2SiO_4 is added to the chemical composition, without affecting the other axes. This is called morphotropy.

In the Andalusite Group of minerals—*cyanite,* blue-bladed, and also gray and green with white intercalations, occurs in schists, and forms schists. It makes effective mineral specimens, and the gemmy blue terminated crystals from Switzerland, on a scaly white paragonite, make attractive objects. *Dumortierite* has in-
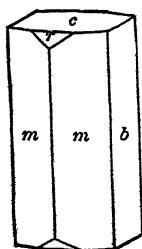
Fig. 372
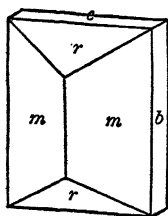
Fig. 373
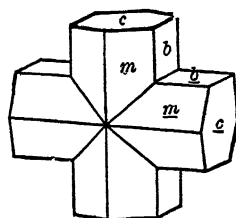
Fig. 374
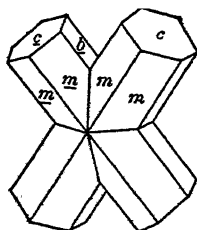
Fig. 375
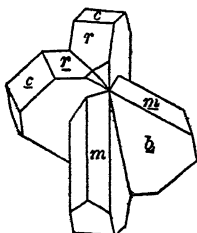
Fig. 376
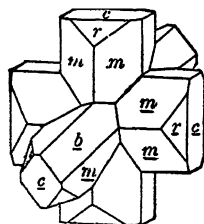
Fig. 377
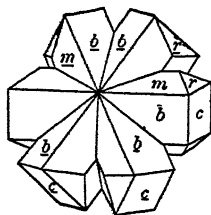
Fig. 378
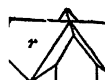
Fig. 379

PLATE 22

terest from its rarity, occurring in New York island (where it was long considered a threadlike tourmaline) at Clip Arizona, and in San Diego Co. Cal. It is a delicate bluish mineral appearing oftentimes in cottony tufts penetrating feldspar.

HYDROUS SILICATES

Under this division of the silicates are arranged a number of silicates which contain water as an essential constituent, and it
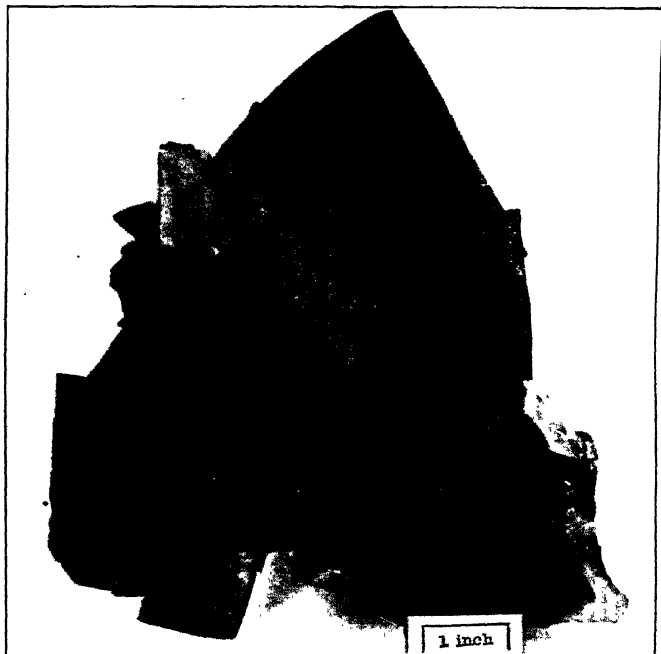
ORTHOCLASE (Adularia)
Graubunden, Switz.
Bement Collection, American Museum of Natural History

MICROCLINE
Crystal Peak, Col.
Bement Collection, American Museum of Natural History

was supposed that a division into a series similar to the anhydrous silicates could be made of them, but the uncertainty in each case as to whether the water was basic and how much of it was so, put to confusion this plan. By considerations drawn, however, from other features, as crystallization, a provisional classification on this basis was affected. Thus, Apophyllite was considered a *unisilicate,* because the tetragonal system in which it crystallizes was unknown in the anhydrous bisilicates, though common amongst the anhydrous unisilicates. These divisions have been modified in the recent edition of Dana's "System," but for most purposes of arrangement the previous method can be retained, and at the present time the arrangement in some cabinets follows the older work. The hydrous silicates are characterized by low specific gravity, by inferior hardness, are in many instances decomposable by acids (zeolites) and are commonly products of alteration. The succession and position of the species follows:

Species.	*System.*	*Composition.*
Pectolite.	Monoclinic.	Silicate of soda and lime.
Okenite.	Orthorhombic.	Silicate of soda and lime.
Laumontite.	Monoclinic.	Silicate of lime and alumina.
Dioptase.	Hexagonal.	Silicate of copper.
Chrysocolla.	Amorphous.	Silicate of copper.
Catapleiite.	Hexagonal.	Silicate of zirconia and soda.
Xylotile.	(Fibrous.)	Altered asbestus?
Calamine.	Orthorhombic.	Silicate of zinc.
Prehnite.	" .	Silicate of lime and alumina.
Zonochlorite.		(impure prehnite.)
Quincite.		
Thorite.	Tetragonal.	Silicate of Thoria.
Tritomite.	Hexagonal.	Silicate of Lanthana.
Pyrosmalite.	"	Silicate and chloride of manganese and iron.
Cerite.	Orthorhombic.	Silicate of ceria.
Apophyllite.	Tetragonal.	Silicate of lime and potassium fluoride.
Carpholite.	Monoclinic.	Silicate of manganese and alumina.
Gismondite.	"	Silicate of lime and alumina.
Allophane.	Amorphous.	Silicate of alumina.
Levynite.	Hexagonal.	

ZEOLITES.

Species.	System.	Composition.
Thomsonite.	Orthorhombic.	Silicate of soda, lime and alumina.
Natrolite.	"	Silicate of soda and alumina.
Scolecite.	Monoclinic.	Silicate of lime and alumina.
Mesolite.	Triclinic.	
Analcite.	Isometric.	Silicate of soda and alumina.
Chabazite.	Hexagonal.	Silicate of lime and alumina.
Faujasite.	Isometric.	
Gmelinite.	Hexagonal.	Silicate of soda, lime and alumina.
Phillipsite.	Monoclinic.	Silicate of lime and alumina.
Harmotone.	"	Silicate of baryta & alumina.
Stilbite.	"	Silicate of lime and alumina.
Heulandite.	"	Silicate of lime and alumina.
Brewsterite.	"	Silicate of lime and alumina with soda or potash

MARGAROPHYLLITES.

Talc.	Foliated.	Silicate of magnesia.
Pyrophyllite.	"	Silicate of alumina.
Pihlite.	"	
Smectite.	"	
Montmorillonite.	Massive.	
Sepiolite.	"	
Chloropal.	"	Silicate of iron, etc.
Stilpnomelane.	Foliated.	
Serpentine.		Silicate of magnesia.
Deweylite.	Amorphous.	
Cerolite.	"	
Hydrophite.	"	
Bastite.	"	
Genthite.	"	
Kaolinite.	"	Silicate of alumina.
Saponite.	"	
Pholerite.	"	
Halloysite.	"	
Pinite.		
Kirwanite?		

Species.	System.	Composition.
Fahlunite.	Micaceous.	
Oellacherite.	Micaceous.	
Margarodite.	"	
Voigtite.	"	
Cookeite.	"	
Vermiculite.	"	
Euphyllite.		
Jefferisite.		
Penninite.		
Cronstedite.		
Phyllite.		See larger text books.
Margarite.		
Chloritoid.		
Seybertite.		
Chrome ochre.		
Walchonskoite.		
Chlorophanite.		
Klipsteinite.		
Chamoisite.		
Alvite.		

The group of zeolites with those species which are closely associated with them in place, viz, apophyllite, laumontite and gismondite, etc., easily assume prominence amongst the hydrous silicates, from their great beauty, their brilliant luster and coloring, and the delicacy and finish of their crystallization. Considered in their scientific aspect the zeolites are related to the feldspars, as they are silicates of alumina, soda, lime, with potash, baryta and strontia, while magnesia and iron are absent, and it has been shown that their fusion and recrystallization frequently result in the formation of a feldspar. But they otherwise present very obvious points of difference; they assume a variety of crystallization, quite contrasted with the formal uniformity amongst feldspars, and they are as a class secondary minerals resulting from the change by decomposition and rearrangement of the components of igneous rocks, less commonly of granite, gneiss, etc. The formation of chabazite, harmotone, and stilbite upon the gneissic rocks of New York Island, is an excellent illustration of their more rare occurrence, and in the cabinet of the New York Mineralogical Club (Am. Mus. Nat. Hist.) splendid examples are exhibited of this association.

The zeolites and related minerals are well illustrated in cabinets. The beauty of color in prehnite, the crowded acicular radiations in pectolite, the square prisms, with perfect cleavage parallel to the base, of apophyllite and its delicate shades of color, the fan-shaped rosettes of stilbite, the interesting crystals of analcite, and the pyramidal terminations of the slender prisms of natrolite, with numerous alternations of needlelike spheres, form an attractive combination, making with the other more uncommon species almost the most beautiful section in Mineralogy. The term *zeolite* was first used in 1756 and was derived from ζεω, *to boil* and λιθος, *stone;* a reference to the swelling of the mineral upon fusion. These minerals occur in cavities, crevices, seams, and irregular openings, or on flat surfaces in volcanic or metamorphic rocks, where through the action of carbonic acid and water, carrying more or less alkali, the original rock has undergone softening and chemical change, and in the resulting mass of claylike consistency, these minerals have slowly formed.

The classic instances of their contemporaneous formation at the hot spring of Plombieres has been often quoted. There in the remains of the old Roman masonry, chabazite has been found (a silicate of alumina) implanted on the bricks, while apophyllite occurs in immediate juxtaposition on the cement which held the bricks together. At Weehawken and Paterson, New Jersey, the extraordinary profusion of these minerals developed in veins in the trap rock, enormously popularized these minerals and supplied the cabinets of the world with unequalled specimens.

Zeolites are typically hydrous minerals. They lose their water upon exposure, or when in dessicators with sulphuric acid, and with the loss they lose translucency and become opaque. This water is recovered in a damp atmosphere and their translucency returns, as if, to quote Miers, "the crystal edifice is not destroyed when the water is removed, and that the water can re-enter the meshes of the structure." Twinning is very prevalent in the zeolites, loss of water changes their optical behavior, and they are uniaxial or biaxial in the same species (chabazite), and isomorphous mixtures are suggested.

In the newer arrangement of the mineral groups, pectolite, catapleiite, calamine, dioptase, prehnite, thorite, tritomite, cerite, carpholite, are placed with the anhydrous class, though all, excepting tritomite and dioptase, have water constituents separable in a closed tube.

Pectolite, in sheeny, glistening radiating spheres which in cross sections show blended fan-shaped groups of needles, and
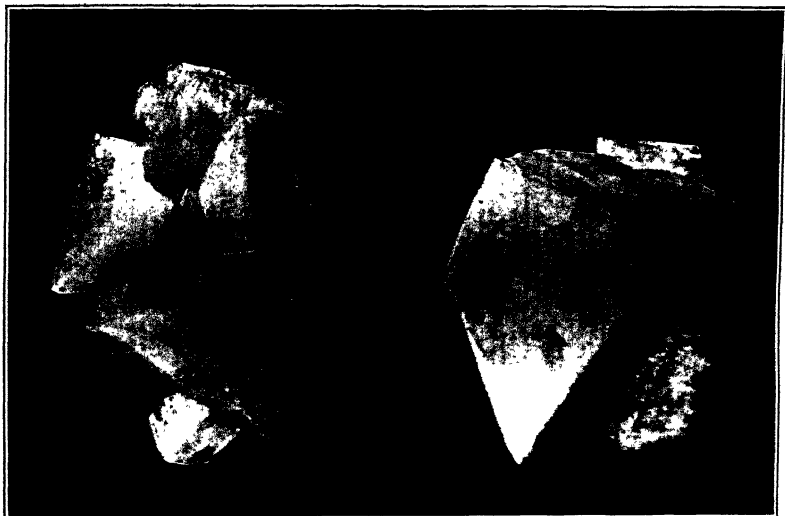
ORTHOCLASE (Adularia)
Gaveradi and Tavetsch, Switz.
Bement Collection, American Museum of Natural History
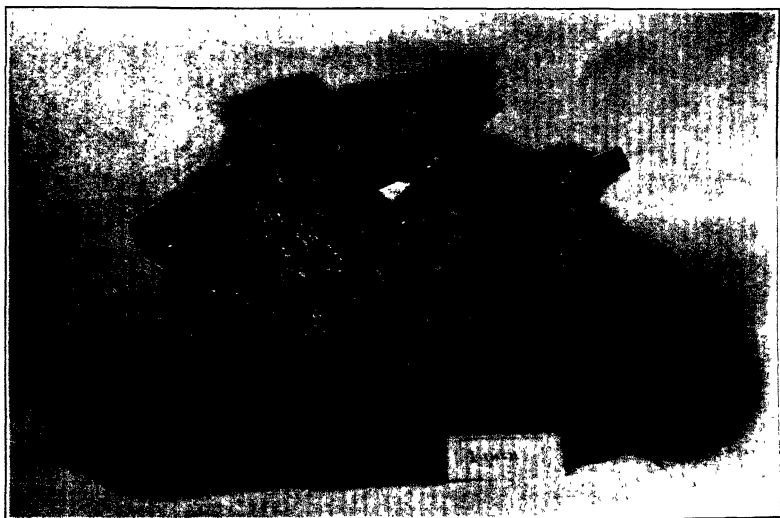
PYROXENE
Nordmark, Sweden
Bement Collection, American Museum of Natural History

which are often exquisitely terminated by crystal faces, while green prehnite adds to their beauty, as a frequent associate. These are generally from Bergen Hill, N. J. or from Paterson, and are sometimes of large dimensions, while alteration supervening breaks them into softer aggregates, and changes the snowy white surface to a dull gray. Massive pectolite from California and Michigan are of interest.

Okenite, pale yellow or white in a acicular matted balls, from Greenland and Iceland, *laumontite,* in white frail spires of oblique crystals, which quickly crumble upon loss of water, *dioptase* deriving its name from "I see through," in allusion to an interior shine it has, in green hexagonal prisms ended with rhombohedrons, lead this section. Dioptase only loses water at a red heat. It is found in Siberia, and also, in the same habit, in the French Congo district in Africa. *Chrysocolla* an amorphous green to blue mineral from Clifton Arizona, and producing charming effects when underlying a quartz covering of crystals as seen in specimens from Gila Co., Arizona, follows. *Catapleiite* a rare mineral, developed in plates from Langesund fiord, Norway; *prehnite* in green globes, stalactitic, and encrusting, varying in tint; *thorite* in low octahedrons from Langesund fiord, Norway, with remarkable tetragonal groups from Arendal (*orangite*); *pyrosmalite* in greenish yellow hexagonal prisms associated with black tourmaline; *bertrandite* of a delicate green in wedge-shaped (hemimorphic) crystals from Auburn Maine, or in feldspar from Bohemia; *cerite* massive; *allophane* (now succeeding talc), in bluish green encrustations; *gismondite* (zeolitic) in interfering clusters in cavities in trap, precede the zeolites.

Calamine, a silicate of zinc, contains water and was regarded as a hydrous silicate. This water is now considered basic, and the mineral has been placed amongst the anhydrous silicates. Its crystals, shown in great perfection in all large collections, are differently terminated at their opposite ends, and hence are known as hemimorphic. The beautiful snow-white crystallizations in meandriform masses, of New Jersey, have especial prominence, but as an ore of zinc it is more abundant in Missouri, where it has apparently formed in the midst of zinciferous clays.

THE MARGAROPHYLLITES

This section, no longer retained in the later "System" of Dana's, embraced a group of soft, massive or foliated minerals, many of them micaceous in aspect, all containing water, and to a

great extent the products of the alteration of other minerals to which they could be referred by the graded series of progressive changes, which were intermediate between the original species and its secondary derivatives. They were broken up into subordinate groups, as the talc, serpentine, chlorite, pinite, and others. Their nature is considered the same, but many of them have been relegated to varietal positions under the minerals from which they are related, as *pinite* and its varieties are now placed with muscovite, which they resemble, as *fahlunite* and *esmarkite,* with iolite, from which they were derived.

Conspicuous amongst these micaceous products is *serpentine,* silicate of magnesia, although this mineral is usually massive in structure. Serpentine is not an original species. In all cases it is the result of change, and chrysolite, pyroxene and amphibole are the more common parents. Examples of its many phases are given in large collections, and blocks showing the alternation of the fibrous (chrysotile) and the massive serpentine are exhibited. The crystals of chrysolite from Snarum, Norway, are especially interesting, as they are completely changed to serpentine and are imbedded in serpentine as well. Long fibres from Maryland, laminated specimens from Staten Island, and the densely granular and sea-green rock (williamsite) illustrate its numerous phases and conditions of color and texture. Most so-called *asbestus* is fibrous serpentine.

Ripidolite (Clinochlore), a silicate of magnesia and alumina, is a pretty green mineral exhibiting in thin sheets a very beautiful bottle-green color; it crystallizes in deceptive monoclinic prisms which appear very much like hexagonal crystals. Examples from Texas, Pa., on slate, are always noticeable, and the larger sheets give the characteristic subtranslucent leek-green appearance with white reflections. Fine specimens from Tilly Foster are present in large collections.

Prochlorite, though indifferently represented in collections, typifies the *scale* micaceous hydrous minerals, those formed of interbedded and overlapping scales, or in crystals easily separated into plates. Chlorite forms a variety of schistose rocks and frequently, as in examples from Chester, Mass., forms an enveloping matrix around other minerals as, in this case, garnet. It also occurs as a green dust included in quartz.

NIOBATES, COLUMBATES, TANTALATES

In this group of minerals the mineralogist encounters a series of compounds embracing the more rare elements combined with

iron, lime and magnesia, developed in granites in individual crystals, or, as in the case of Samarskite, massive. They have a hardness between 5 and 6, seldom exceeding the latter, and are brown to black in color. The orthorhombic system prevails amongst them. The group is not exhaustively or very fully represented in collections. They seldom attract the collector, except in instances where the crystallization is well marked and the faces of the crystals are brilliant and definite, as in Columbite.

Besides the following list, *hatchettolite, sipylite, tantalite, tapiolite, yttrotantalite, hielmite,* should be considered in this group, and under recent examination, with the increased interest in radioactivity, and the new electrical applications of tantalum, the section has gained wonderfully in mineralogical value. Euxenite contains small quantities of germanium. The American localities for these minerals have some interest; as Chesterfield, Mass. and Amelia Court House, Va. for microlite; Mitchell Co. N. C. for samarskite and hatchettolite; Burke Co. N. C. for fergusonite; Standish Me., Haddam, and Portland, Conn., for columbite, while Sipylite with its twenty-three elements is found only at Friar Mt., Amherst Co., Va.

NIOBATES, TANTALATES, ETC.

Species.	System.	Composition.
Microlite.	Isometric.	Tantalate of lime.
Pyrochlore.	"	Columbate of lime and ceria.
Tantalite.	Orthorhombic.	Tantalate of iron and manganese.
Columbite.	"	Columbate of iron.
Yttrotantalite.	"	Tantalate and columbate of yttria, erbia and iron.
Samarskite.	"	Columbate and tantalate of yttria, ceria, iron and urania.
Aeschynite.	"	Columbo-titanate of ceria, thoria and lanthana.
Polymignite.	"	Like Aeschynite.
Euxenite.	"	Columbo-titanate of yttria, urania, erbia and ceria.
Polycrase.	"	Like Aeschynite.
Hielmite.	"	
Fergusonite.	Tetragonal.	Columbate of yttria, erbia, and ceria.

PHOSPHATES, ARSENATES, ANTIMONATES

The minerals embraced under this section are unions of various bases with phosphoric, arsenic and antimonic acids. They are

divided into anhydrous and hydrous salts, the former having a hardness from 3 to 6 and crystallizing usually in all the systems except the isometric. They are various in color and, with the hydrous species, extend over a wider range of colors than any other group except the carbonates.

Species.	System.	Composition.
Apatite.	Hexagonal.	Phosphate of lime with chlorine and water.
Pyromorphite.	Hexagonal.	Phosphate and chloride of lead.
Mimetite.	"	Arsenate & chloride of lead.
Monazite. (Turnerite).	Monoclinic.	Phosphate of ceria, lanthana, yttria, didymia, thoria, etc.
Wagnerite.	"	Fluophosphate of magnesia.
Triplite.	"	Fluophosphate of magnesia and iron.
Triphyllite.	Orthorhombic.	Phosphate of lithia, iron and manganese.
Beryllonite.	"	Phosphate of beryllia and soda.
Herderite.	"	Fluophosphate of lime and alumina.
Amblygonite.	Triclinic.	Fluophosphate of lithia, alumina and soda.

HYDROUS PHOSPHATES, ARSENATES, ETC.

Struvite. (Redondite)	Orthorhombic.	Phosphate of ammonia and magnesia.
Romeite.	Tetragonal.	Antimonate of lime.
Pharmacolite.	Monoclinic.	Arsenate of lime.
Vivianite.	"	Phosphate of iron.
Erythrite.	"	Arsenate of cobalt.
Annabergite.	"	Arsenate of nickel.
Kottigite.	"	Arsenate of cobalt with zinc.
Libethenite.	Orthorhombic.	Phosphate of copper.
Olivenite.	"	Arsenate of copper.
Euchroite.	"	Arsenate of copper.
Tyrolite.	"	Arsenate of copper.
Cornwallite.	Massive.	Arsenate of copper.
Liroconite.	Monoclinic.	Arsenate of copper.
Pseudomalachite.	Massive.	Phosphate of copper.
Chalcophyllite.	Hexagonal.	Phosphate of copper.

PYROXENE
Renfrew Co., Ontario, Canada
Bement Collection, American Museum of Natural History
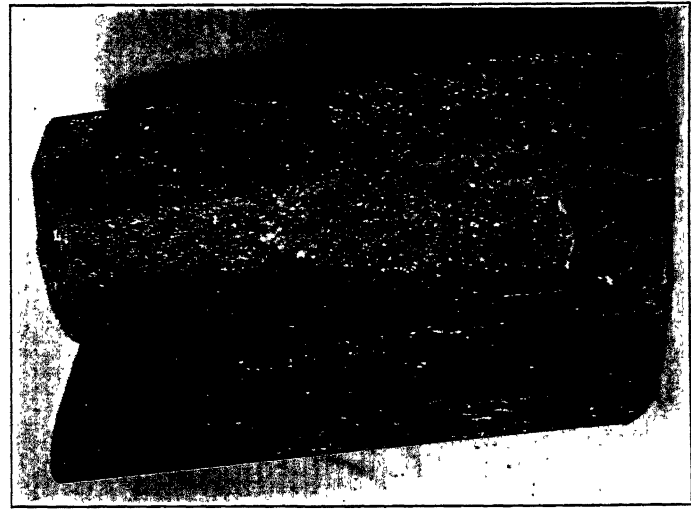
PYROXENE
Bathurst, Ontario, Canada
Bement Collection, American Museum of Natural History

Species.	System.	Composition.
Lazulite.	Monoclinic.	Phosphate of alumina and magnesia.
Clinoclasite.	"	Arsenate of copper.
Scorodite.	Orthorhombic.	Arsenate of iron.
Wavellite.	"	Phosphate of alumina.
Childrenite.	"	Phosphate of alumina, iron and manganese.
Pharmacosiderite.	Isometric.	Arsenate of iron.
Turquois.	Amorphous.	Phosphate of alumina.
Peganite.	Orthorhombic.	Phosphate of alumina.
Variscite.	"	Phosphate of alumina.
Dufrenite.	"	Phosphate of iron.
Cacoxenite.		Phosphate of iron.
Tavistockite.		
Torbernite.		Phosphate of copper and urania.
Autunite.		Phosphate of lime & urania.
Borickite.		
Bindheimite.		Antimonate of lead.

Apatite, the phosphate with fluoride of lime, crystallizes in six-sided prisms terminated by hexagonal pyramids, or in its more aberrant and beautiful forms in short prisms variously modified on terminal edges. Examples of much complexity have been described, notably amongst which are the crystals from North Carolina detected by Hidden. It assumes many tints and the varnishedlike surfaces, with their intermingled and interveined hues, from Renfrew Co., Canada, are objects of much mineral beauty. Many of these crystals are exhibited and amongst them will be noticed cavities, irregular cellular excavations and pits. Taken in conjunction with the rounded form of many of the Canada apatites, these cavities have been regarded by Professor Hunt as having been caused by partial solution after deposition, and by Dr. Emmons by fusion. The development of apatite in Canada is on an immense scale and occurs in vein deposits in pyroxenic and hornblendic rock, and occasionally associated with limestone. The crystals are sometimes enormous, weighing in one instance seven hundred pounds, and associated with zircon, wernerite, titanite, pyroxene, and micas of great beauty and perfection. Most of these minerals from Canada in the apatite region are exhibited under their separate species in cabinets. Besides those in less unusual excellence are numerous other minerals, as fluorite, garnet, epidote, tourmaline, quartz, feldspars, and graphite. The exquisite amethystine crystals from Bohemia and

the snow-white prisms, delicately truncated with pyramidal and scalenohedral planes from Switzerland, are in collections. Varietal names prevail under apatite to designate certain peculiarities of color or aggregation, as *asparagus stone* for the yellowish green specimens, *lasur apatite* for a sky-blue variety, *francolite* for greenish stalactitic masses, *eupychroite* for concretionary nodules separable into concentric shells, *staffelite* for drusy or stalactitic varieties from Staffel, with others less distinct.

Pyromorphite, the phosphate with chloride of lead, crystallizes in the hexagonal system with a narrow range of crystalline variation, presenting six-sided prisms, terminal pyramidal faces, and a basal plane. These prisms are often curved and assume barrel-shaped forms. It also occurs in globular, irregular and concretionary groups. The specimens from Phœnixville, Pa., are of excellent quality, and their dark green, tapering crystals, with slightly hollowed ends, and varying from moderate dimensions to strawlike crystallizations matted together in vivid crusts over quartz, are amongst the mineralogical gems of American cabinets. Specimens from this locality are often exhibited.

Mimetite, the arsenate and chloride of lead, resembles pyromorphite, and this imitation has justified the name, which means imitation, from the Greek μιμητής. The brown, curved, barrelshaped crystals from Dry Gill, Cumberland, England, shown are widely distributed in cabinets. It also occurs in crusts and sometimes rounded in spheres.

Beryllonite has interest as comparatively a new mineral, the phosphate of beryllia and soda, and has been tentatively used as a gem. It possesses a structural peculiarity containing canals and fluid cavities in parallelism with the vertical axis.

Herderite, a phosphate of beryllia and lime has also interest from its mineralogical rarity and the excellence of the crystals found at Stoneham, Maine, where the beryllonite also was discovered.

Herderite had been known, but its exact composition was unsettled until the discovery of the crystallized mineral at Stoneham determined its chemical character.

Monazite in large, yellowish brown crystals from Norway, and in smaller and more perfect ones from Alexander Co., N. C. is found in this section. It is an important source of thorium, and this element is obtained industrially from the monazite sands of North Carolina and Brazil. Xenotime is seen in this group, in tetragonal pyramids from Norway, in crowded groups, and in individual low crystals on granite from N. Y. island. *Wagnerite* in large glassy

yellow-brown crystals is found at Werfen Salzburg, and in white compressed crystals from Bamle, Norway. *Triplite* and *triphyllite,* the manganese and lithia-manganese phosphates, in dark masses (crystals rare) are seen near at hand, the latter graduating into *lithiophilite.* And here is *amblygonite* a lithia phosphate found at Paris, Me. and in useful quantities in the wonderful lithia mineral deposits in San Diego Co. S. California.

At Branchville, Connecticut, in a vein of albitic granite. a marvellous richness of mineral occurrences has been described. The species number almost forty, and among them a variety of phosphates of exceeding rarity as *eosphorite, lithiophilite, reddingite, dickinsonite, natrophilite, fairfieldite,* which may be seen in matured collections.

The hydrous phosphates, arsenates, etc., present a long and variously colored throng of members which compose a very attractive section in the mineral kingdom, and reveal an entertaining range of color. *Struvite,* in white or blackened hemimorphic orthorhombic crystals, formed in ordure at Hamburg, at the site of an old church where dung has accumulated over a swamp, in which the crystals are found, is interesting from the ease with which microscopic crystals of the same salt can be artificially formed.

Here the visitor encounters *pharmacolite* in plumose nests from Saxony followed by vivianite.

Vivianite, a hydrous iron phosphate, occurs abundantly in New Jersey, from which State specimens are exhibited. Here it is extensively developed in the green sands of Mullica Hill, the result of the decomposition of organic bodies, as in the form of thin needles (mullicite) it fills the cavities of belemnites, and is disseminated in grains through the clays and cretaceous sands. Strong and deeply colored crystals from Cornwall are often exhibited. Broad strong crystals of vivianite come from Victoria.

The group of arsenates and phosphates of copper which follow are interesting from diversities of structure, etc., coincident with differing amounts of water. They display also variations in color, luster, hardness and gravity, the larger presence of water being in a general way significant of a softer texture. The mineral phosphates or arsenates were, as Dana observes, not formerly separated, but these green compounds were generally classed as *chrysocolla* and *malachites,* names now assigned to the silicate and carbonate of copper respectively. Amongst the phosphates of alumina besides the attractive *wavellite,* examples of which are included in collections, the

Erythrite in radiating needles and crystals from Schnee-berg, Sax., with silkenlike mats from Chili, or in the form of an earthy rose-ochre, is a striking mineral; *annabergite* is shown in crusts or in delicately aggregated needles from Laurium Greece, *köttigite* in pink films (the arsenate of zinc colored by cobalt), *libethenite* in good dark-green crystals from Cornwall, England, from Libethen, also from Hungary, from the Ural Mts. from Utah (Tintic Dist); *olivenite* well crystallized from Utah, and Cornwall, England, from France; *euchroïte* from Cornwall, and from Hungary in superb crystals on schist; *tyrolite* from Utah, in bluish-green crusts; *cornwallite* from Cornwall; light-blue *liroconite* from Cornwall; *pseudomalachite* as a massive green mineral suggestive of the compact Russian malachite; *lazulite* conspicuous from its light-blue pyramidal crystals well formed in a sandstone from Grave's Mountain Georgia, occurring with rutile and cyanite; *chalcophyllite* a green phosphate of copper in rhombohedrons or plates from Cornwall; *clinoclasite* also from Cornwall and also in good form from the Tintic Dist., Utah, with a tendency to curve into spheres; *scorodite,* pale green, in pointed crystals or in crusts, in minute crystals in pockets of quartz and limonite in Utah asso-ciated with copper arsenates; *wavellite* in stalactitic aggregates, in spheres, in stellate sections, of green, yellowish-white, brown, white and gray tints, notably from Whitehead Pa., from Bohemia, Saxony, Hungary, Hot Springs, Ark.; *childrenite* in brown crystals, running into the manganese phosphate *eosphorite,* from Devonshire, Eng.; *pharmacosiderite* in cubes or with the tetrahedron; the green crys-tallized, more generally fibrous *dufrenite* contrasting with the yel-low phosphate of iron, *cacoxenite,* make a long series of interesting minerals, among which occur many more not enumerated here.

Turquoise is also here conspicuous. Its popularity as a gem and its interesting association with the pre-columbian history of the continent give it importance. The true oriental turquoise of Persia is a delicate robin's-egg blue, which the green and rather clayey surfaces of the New Mexico mineral does not fairly rival. The mines where the *turquoise* is now exhumed in the Los Cerillos Mts., New Mexico, have been worked by the Mexican Indians for cen-turies, and this stone has been referred to the *Chalchihuitl* of the Aztecs. Much turquoise of excellent color loses its intensity by dry-ing, and many so-called turquoises are fossil bone colored by a phosphate of iron. However, beautiful blue turquoise has been taken from American mines. In Nevada in a light colored porphyry in Esmeralda, Nye and Lincoln Cos. In N. Mex. in Grant, Santa Fe, and Dona Ana Cos. Near turquoise are the admirably colored

HIDDENITE
Stony Point, N. C.
Bement Collection, American Museum of Natural History

PECTOLITE
Bergen Hill, N. J.
Bement Collection, American Museum of Natural History

massive sections of green aluminous phosphate, *variscite,* in flat circular concretions, often traversed by seams. This mineral has acquired much vogue in jewelry. The deposits occur in limestone, rhyolite and sandy-shale formations, in Nevada.

Torbernite and Autunite are attractive minerals from their strong colors, and the former from its tabular crystals, shown in perfection in specimens from Gunnis Lake, Cornwall. *Autunite* approaches very closely to Torbernite in crystallization, and is essentially similar in composition. The former mineral was long considered a copper ore, but though it contains copper it is a phosphate of Urania, as is *Autunite,* which holds lime in about the same proportion as Torbernite does copper. Both species have been found on New York Island.

BORATES

Species.	System.	Composition.
Boracite.	Isometric.	Chloro-borate of magnesia.
Howlite.	Orthorhombic.	Borate of lime.
Borax.	Monoclinic.	Bi-borate of soda.
Ulexite.		Borate of lime and soda.
Colemanite.	"	
Warwickite.	Orthorhombic.	Titano-borate of magnesia.

Borax is the bi-borate of soda, crystallizing very perfectly in large crystals, monoclinic in symmetry, showing prisms, pinacoids, domes and pyramids. Its enormous development in California and Nevada make it of industrial importance, and the admirable clearness and definition of its crystals an attractive feature in cabinets. At Esmeraldo Co., Nevada, it is found in the lower portion of a swamp in crystals of varying size. The remarkable feature of its occurrence here is the fact that its crystals form in an unsaturated menstruum and seem to resist solution when by drainage or rainfall more water has been flooded over their beds. It is also found at Borax Lake, California, and extracted by improvised coffer-dams from the bottom of the lake, as much as 800 pounds being taken from an area four feet square. It is named from *buraq,* an Arabic word.

Ulexite is found in the same locality with borax, in the "cotton bolls" exhibited. It contains lime and is mixed with common salt, gypsum and glauberite, sulphate of soda.

From a crystallographic standpoint the most interesting mineral in this group is *boracite,* which is found in gypsum and anhydrite

at Luneburg Hanover in apparently very perfect isometric crystals viz., cubes, octahedrons, rhombic dodecahedrons; but examination detects that the octahedral faces combined with the cube are not octahedral at all, but right and left tetrahedrons; that indeed one tetrahedron is replaced by the faces of the three-faced tetrahedron at times, while examined under a microscope between crossed nicols in thin sections the mineral is found to be biaxial, and has been interpreted (Mallard) as a group of twinned orthorhombic crystals. Heated to 265° it becomes isotropic or its physical qualities agree with its isometrism.

Among the borates *Colemannite* from San Bernardino Co. Cal. is now exhibited in specimens of surpassingly beautiful crystallized groups.

TUNGSTATES, MOLYBDATES, VANADATES

Species.	*System.*	*Composition.*
Wolframite.	Monoclinic.	Tungstate of iron and manganese.
Hübnerite.	"	Tungstate of iron and manganese.
Scheelite.	Tetragonal.	Tungstate of lime.
Wulfenite.	"	Molybdate of lead.
Descloizite.	Orthorhombic.	
Vanadinite.	Hexagonal.	Vanadate of lead.
Pucherite.	Orthorhombic.	Vanadate of bismuth.
Stolzite.	Tetragonal.	Tungstate of lead.

Wolframite presents usually a characteristic acute-angled prism, much striated vertically; often it occurs in blades (Hübnerite) and it is found massive granular also. It is frequently mistaken for tin ore, and where it contaminates that ore it renders it metallurgically difficult to treat.

Scheelite is an interesting tungstate from its crystallographic features, since it assumes pyramidal forms of different orders, that of the third order being so related to the axes as that the latter cut its faces at unequal distances from the pyramidal edges. Scheelite is associated with rare or beautiful minerals, as topaz, cassiterite, gold; it is frequently altered to wolframite through contact and solution in iron waters.

Wulfenite hardly claimed such a conspicuous position on the merits of its beauty, as it has since the discoveries in Nevada and Arizona revealed crystals of so much splendor, unusual size and

deep color. Some of these exhibited, of a yellow and vermilion color, are also beautiful in their crystalline perfection. They are four-sided tables, truncated or beveled on their edges by plans which are the faces of pyramids.

Vanadinite and **Descloizite** were also rare and indifferent minerals until the masses and crystal surfaces from Arizona and New Mexico made them familiar to collectors, in their finest and most attractive forms. *Vanadinite* resembles pyromorphite in its six-sided prisms, their slightly cavernous ends, and in their grouping. *Descloizite* is distinguished in its form from Vanadinite by its low pyramidal summits and transverse extension, its prismatic width. Stolzite in wonderful crystals, (yellow-brown) has, in recent years been found at the Broken Hill mines in N. S. Wales.

SULPHATES, CHROMATES

Species.	System.	Composition.
Barite.	Orthorhombic.	Sulphate of baryta.
Celestite.	"	Sulphate of strontia.
Anhydrite.	"	Sulphate of lime.
Anglesite.	"	Sulphate of lead.
Caledonite.	"	
Leadhillite.	Monoclinic.	Sulphato-carbonate of lead.
Glauberite.	"	Sulphate of soda and lime.
Connellite.	Hexagonal.	Chloro-sulphate of copper.
Crocoite.	Monoclinic.	Chromate of lead.
Phaenicochroite.	Orthorhombic.	Chromate of lead.
Gypsum.	Monoclinic.	Sulphate of lime.
Polyhalite.	"	Sulphate of lime & magnesia.
Hanksite.	Hexagonal.	
Epsomite.	Orthorhombic.	Sulphate of magnesia.
Morenosite.	"	Sulphate of nickel.
Blödite.	Monoclinic.	Sulphate of soda & magnesia.
Chalcanthite.	Triclinic.	Sulphate of copper.
Alunogen.	Monoclinic.	Sulphate of alumina.
Goslarite.	Orthorhombic.	Sulphate of zinc.
Melanterite.	Monoclinic.	Sulphate of iron.
Alum.	Isometric.	Sulphate of alumina and potash.
Copiapite.	Hexagonal.	Sulphate of iron.
Linarite.	Monoclinic.	Sulphate of copper.
Alunite.	Hexagonal.	Sulphate of alumina and potash.

Species.	System.	Composition.
Pickeringite.	Monoclinic.	Sulphate of alumina and magnesia.
Raimondite.	Hexagonal.	Sulphate of iron.
Brochantite.	Orthorhombic.	Sulphate of copper.
Uranocher. (Medjidite Zippeite.)	"	
Cyanotrichite.	"	Sulphate of copper.
Langite. (Woodwardite.)	"	Sulphate of copper.
Jarosite.	Hexagonal.	Sulphate of iron and potash.

Barite, the sulphate of baryta, is a well crystallized and handsome species, not distinguished by crystalline variety, but often grouped in divergent bunches or in sheaf-like aggregates of radiating plates frequently massive and banded, and occasionally globular, fibrous and granular. The crystals are commonly tabular, somewhat modified on the edges, and are frequently tinged yellow, red, green, blue and brown. It is stalactitic also, and the curious woodlike concentric, fibrous structure, shown in sections, from Derbyshire, England, is an example of this habit. Encrustations of other minerals give interest and beauty to specimens of barite, as siderite, pyrite, calcite, chalcopyrite, galenite, and gypsum. Barite accompanies metallic veins and is of common occurrence in lead mines. Crystals of enormous size have been found in lead mines, as in England, where a crystal weighing one hundred pounds was found in the mud of a mining pit. Capital examples of its association with galenite are shown, and the species is always instructively illustrated in suites of specimens showing its varied appearance and association.

In recent years extraordinary beautiful specimens from England have been found in green, blue, brown and yellow colors, and with a variety of crystal forms of superb perfection. The barites always attract observation; the aggregates of flat blue plates, the long yellow to brown prisms, the white margined, square crystals from Utah, the heavy plates from Cheshire, Conn., etc.

Celestite, the sulphate of strontium, is a constant companion of the sulphur of Girgenti, Sicily, and its white crystals delicately combined with the yellow of the sulphur form mineral specimens of great beauty. Celestite derives its name from the shades of blue which in some specimens suffuse the crystals. In cabinets examples possessing this blue tint are shown from Strontian Is-

PECTOLITE

W. Paterson, N. J.

Bement Collection, American Museum of Natural History

land, Lake Superior. Some of these are often of remarkable size. It is also shown with colemanite, from California.

Gypsum, the sulphate of lime combined with water, is a prominent mineral and its transparent plates often enclosing foreign crystallizations or displaying a satin sheen from its fibrous surfaces (satin spar), are objects of beauty. The crystals from Poland, Ohio, are characteristic; twinning is common and the so-called arrow-points (examples may be exhibited from Germany) are the result of this crystalline union. The crystals are frequently curved in their prolongations, and foamlike or crested sprays are formed of considerable prettiness. The massive gypsum is found extensively in New York, Michigan and Nova Scotia, and examples may be seen from that region. Examples of crystallized gypsum from St. Mary's Co., Mo., in which a series of spearlike projection radiate from a solid center, each of which is made up of coalescing and confluent crystals, are sometimes seen in cabinets. Specimens of some interest come from the lignite from Hardeman Co., Texas, which is filled, in its intercellular spaces, with plates or scales of gypsum, a deposit which seems to have accompanied the fossilization of the wood itself, and may have been precipitated from the mineral waters by which this ancient vegetation was covered. The beautiful slabs of selenite from Bologna, Italy, illustrate the transparent varieties of gypsum as do the ice-like masses from Ciancianna, Sicily.

Anglesite, the sulphate of lead, accompanies lead ores, and as here shown crystallizes over the surface and in the depressions of the galenite, from which it was derived. Anglesite from New South Wales in brilliant strings of crystals is recent. Numerous other sulphates are included in this section, and amongst them are the two chromates *Crocoite* and *Phoenicochroite,* which strike the eye by their red color, and whose origin may have been similar to the method used for artificially forming one of them, phoenicochroite, viz. by solutions of potash chromate coming in contact with galenite. The crocoite from Tasmania is of extraordinary beauty. The sulphates doubtless arose from the prevalent formation of sulphuric acid in the decomposition of pyrite. They are usually secondary and efflorescent, sometimes, as with gypsum, their formation being apparent where acid vapors, escaping from volcanic fumaroles, come in contact with lime from the decomposing lavas, and the sulphate of lime crystallizes in their proximity. Instructive specimens of *Alunite* occur in collections from New York Island, showing a spherical deposit of natural alum upon gneiss. Here the pyrite decomposing has formed sulphuric

acid, which in turn has reacted upon the changing scales of mica and grains of feldspar and a double sulphate of alumina and potash has resulted, or the mineral *Alunite*.

Anglesite from Monte Poni Sardinia with galena and from Phoenixville, Pa. is instructive.

Hanksite in broad hexagonal intersecting tables from California is interesting. Among these crowding and not always easily separable sulphates are seen *leadhillite* from Granby, Mo. in light green crystals, *brochantite* in deeper greens from Utah and Arizona, *caledonite* in green drusy surfaces from Sardinia, Scotland and California, *linarite* in blue crystals and crusts from Cumberland and California, *goslarite* in white absorbent masses, *melanterite* in nodules and films, *morenosite* in white stalactites, *chalcanthite* in bright blue wedges or strips and masses, the many hued sulphates of iron, the velvety green of *herrengrundite* from Hungary, and the *langite* in open cellular surfaces of light blue, from Cornwall.

CARBONATES

Species.	System.	Composition.
Calcite.	Hexagonal.	Carbonate of lime.
Dolomite.	"	Carbonate of lime and magnesia.
Siderite.	"	Carbonate of iron.
Rhodochrosite.	"	Carbonate of manganese.
Smithsonite.	"	Carbonate of zinc.
Mesitite.	"	Carbonate of iron and manganese.
Aragonite.	Orthorhombic.	Carbonate of lime.
Bromlite.	"	Carbonate of lime & baryta.
Witherite.	"	Carbonate of baryta.
Cerussite.	"	Carbonate of lead.
Hydromagnesite.	Monoclinic.	Carbonate of magnesia.
Barytocalcite.	"	Carbonate of lime & baryta.
Phosgenite.	Tetragonal.	Chloro-carbonate of lead.
Natron.	Monoclinic.	Carbonate of soda.
Hydrodolomite.	Massive.	Carbonate of lime and magnesia.
Hydrozincite.	"	
Zaratite.	?	Carbonate of nickel.
Aurichalcite.	Monoclinic.	Carbonate of zinc & copper.
Malachite.	"	Carbonate of copper.
Azurite.	"	Carbonate of copper.
Bismutite.	Earthy.	Carbonate of bismuth.
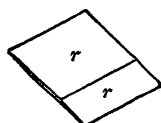
Fig. 380
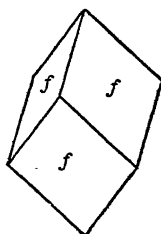
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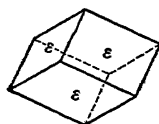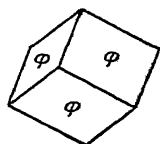
Fig. 382

Fig. 383

Fig. 384
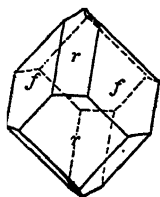
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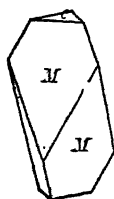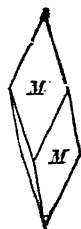
Fig. 386

Fig. 386a

Fig. 387
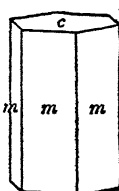
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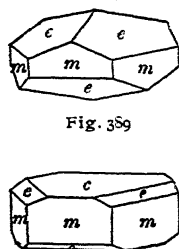
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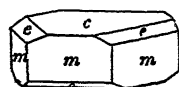
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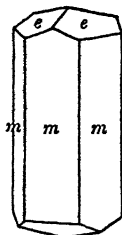
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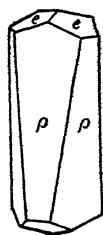
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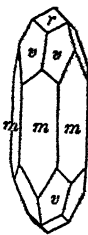
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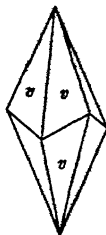
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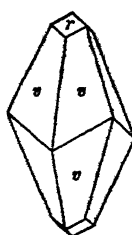
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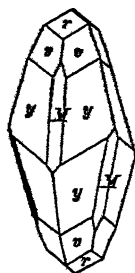
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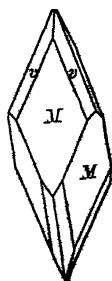
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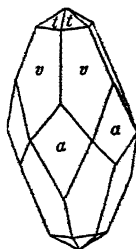
Fig. 398

Fig. 399

Fig. 400

PLATE 23
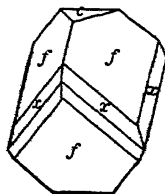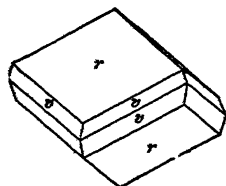
The carbonates as constituting, in carbonate of lime and carbonate of magnesia, the limestones, as forming some of the valuable ores, carbonate of iron, carbonate of zinc, carbonate of copper, and because of the great and useful beauty of many of them, marbles, malachite, azurite, Mexican onyx, etc., take perhaps one of the most conspicuous positions in the mineral cabinet. In *calcite* they have a representative of boundless variety and infinite beauty, while many of the other species are equally brilliant. The carbonates have been formed by the combination of carbonic acid with the various bases that make the carbonates, and this union has in a great number of instances been secured through the agency of water carrying the carbonic acid in solution, which has dissolved the base of the salt, the whole being redissolved afterward from a more or less saturated fluid. The carbonate of lime has been supplied to water through the dissolving agency of carbonic acid upon original limestone and partially through the solubility in water of limestone itself, and recrystallization having resulted from these waters, thus stored with carbonate of lime, has produced the splendid and innumerable forms of calcite.

Calcite, the carbonate of lime, is always well represented in cabinets, and its many forms illustrated in numerous specimens. Plate 23 presents some of its numerous crystal forms, amongst which the rhombohedron and scalenohedron are the prevalent terminations in conjunction with the hexagonal prism. In collections are seen the tapering pink scalenohedrons, terminated, from Weardale, England, large cleavage blocks from Lampasas, Texas, interestingly colored with iron oxide; handsome cavelike geodes from Schullsburg, Wisconsin, where the crystallization around the interior is beautifully shown; the paper and rounded pink calcite from Guanajuato, Mexico; the interpenetrating crystals, forming celllike partitions, and coated with quartz, from Anthony's Nose, N. Y.; remarkable cabbagelike spheres of enchained rhombohedrons from the Yellowstone Park, Wyoming; and splendid examples of Iceland spar from Iceland. With these are numerous specimens further illustrating the associations and varying conditions of this wonderful mineral, amongst which the curious ruin marble will be noticed, its mimetic structure arising from faulting and coloration by iron oxide. In the suites of specimens there is a great variety of examples, amongst which the *Argentite,* a pearly laminated calcite, the *lumachella* made up of fossil shells, the penetration twins from England, the calcite saturated with *byssolite* from French Creek and the superb combinations of crystals in white and delicately colored groups are distinguished by beauty or interest.
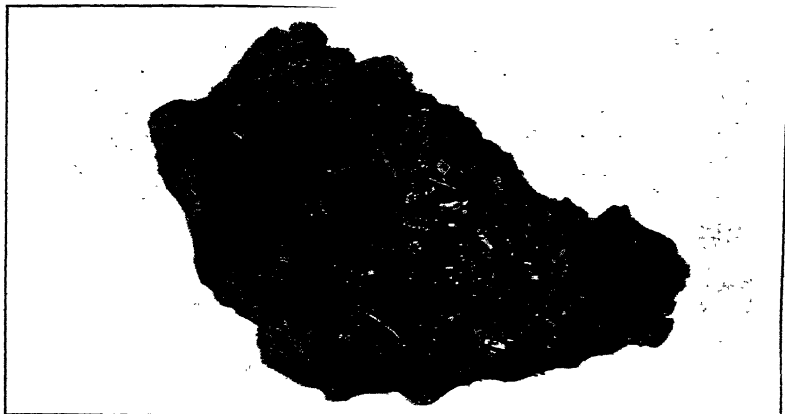
Sterling Hill, N. J.

AMPHIBOLE
Pierrepont, New York
Bement Collection, American Museum of Natural History

The property of double refraction possessed by a great number of minerals is especially strong in calcite. It arises from a splitting up of the ray of light, into two, and as each brings to the observer the picture or image from which it is reflected, the eye discerns two images. Impurities of many kinds are found in calcite and this produces a series of varietal forms.

In large collections the calcites from Mexico occur in beautiful series, the honey crystals from Joplin, Missouri, the large crystals enclosing brilliant copper flakes from Lake Superior, and the endless groups from England, with their tints from hematite admixture and their clear white crystals in flowerlike combinations.

Dolomite, the carbonate of lime and magnesia, is usually distinguished from calcite by its greater hardness, less solubility and the peculiar curved or twisted form of its crystals, which are often a group of smaller individuals, contributing to its warped and broken appearance. It is very commonly pinkish or brown in color, and sometimes has almost a golden surface, as in specimens from Iron Co., Mo. The faces of the crystals are striated and the rhombohedrons are of several series.

Siderite is the carbonate of iron and a valuable iron ore. It crystallizes in the hexagonal system, as calcite and dolomite, being found as rhombohedrons; it passes into hematite and limonite and even magnetite by oxidation. *Sphaerosiderite* is a concretion of siderite in pellets or small spheres, and capital examples have been obtained from Guttengen, N. J., where the mineral has formed secondary crystallizations over the walls of cavities, produced by the removal of calcite.

Rhodochrosite is a pretty pink mineral, the carbonate of manganese, not of frequent occurrence, but of much beauty in some of its phases, in which, as in examples from Kapnik, Hungary, and from Siberia, it combines with quartz to form a delicate and rosy encrustation of crystals. In late years superb specimens have been found near Leadville, Colo.

Smithsonite, the carbonate of zinc, has interest from its pseudomorphous assumption of the forms of calcite and sphalerite. The specimens from Mineral Point, Wisconsin, show this.

Aragonite typifies the orthorhombic section of the carbonates, as calcite does that of the hexagonal, and thus, as a carbonate of lime, displays the dimorphic character of this salt. It derives its name from the province of Aragon, in Spain, where contact twins forming hexagonal prisms are found, but has a wide prevalence throughout the world and is conspicuously prominent in limestone caves, where it has been deposited from saturated waters. Exam-

ples from Dubuque, Iowa, from the Luray Cave, Va., from Mahoning, Pa., Mexico, Bermuda, and Missouri, are frequently exhibited. The solution of lime takes place through the presence in the water of carbonic acid, forming a bicarbonate of lime, and upon evaporation the excess of carbonic acid is dissipated.

These deposits are most diversified and display a singular abundance of capricious and fantastic forms, as aragonite is deposited. Aragonite forms in iron mines, where it encrusts in coralloidal, branching forms the iron, and is called *flos ferri* or the iron flower. It forms in the hot waters of Carlsbad, Germany, the concretionary spheres showing concentric bands, which are often exhibited, also beautiful arborescent bunches and bushlike masses in the caves at Bisbee, Arizona;. while the striking cupolalike crystals attached to each other in groups from Cumberland, England, are examples of its elongated crystallizations. Many examples are delicately and delightfuly colored and specimens of attractive coloration are seen in collections. The exquisite soft and melting shades of the Mexican Onyx are instances of this quality, for this beautiful material is *Aragonite*.

Malachite and **Azurite,** the carbonates of copper, are perhaps, omitting a number of interesting species, the next most important minerals in this group. *Malachite* is distinguished chemically from *Azurite* by less carbonic acid and more water, while in appearance the distinction is self-evident in their contrasted colors. *Azurite,* however, changes to *Malachite,* and in many cases the alternating layers of malachite and azurite demonstrate these interchangeable relations. The magnificent groups of malachite and azurite in the cases of the American Museum of Natural History, the gift of the Copper Queen Mining Company, through Mr. Wm. E. Dodge, is a marvellous example of mineralogical beauty, the superb acicular crystallization appearing like a surface of velvet, and displaying varying shades of color in their tufted and cushionlike clusters, with which is contrasted the smooth and dense surface of the botryoidal mass in the bottom of the case, the plumlike aggregates of the latter crowding irregularly the walls of. a chimney or geode. The deposition of these unrivalled malachites has taken place in cavities into which entered carbonated waters holding the carbonate of copper in solution, and from which it was precipitated in a manner analogous to the formation of aragonite from similarly supersaturated lime solutions. The more consolidated malachites from this region scarcely afford cut and polished surfaces equalling the beautiful concentric and clearer sections of the Russian malachites. They are darkened and injured by manganese

which sensibly soils their color, while the plushlike surfaces, having no stability, break down under pressure and are unavailable for any ornamental purposes. From this region come the beautiful stalactites, and their slight color stain arises from the infiltration of copper salts. The country where these remarkable developments of copper occur is a limestone area and seems to have been invaded, perhaps through eruptive agencies, with enormous volumes of copper-bearing rocks, whose subsequent decomposition and partial leeching by hot waters has concentrated in the soft kaolin or clay bodies of the region, these unique deposits. *Azurite* in attractive specimens, many of them beautifully crystallized, are now illustrated in the collections from Arizona. Alteration of azurite to malachite takes place through the loss of carbonic acid and the addition of water.

The mineral series closes with the resins, oils, coals, bitumens, and asphalts, or those natural residues and products which have been formed by the distillation or slow chemical disassociation of vegetable and animal remains.

Among the remaining carbonates of very striking interest are **Cerussite** and *Phosgenite;* the former in light yellowish stout crystals from Bohemia, in exquisite spires from Sardinia, in silvery bars from Tasmania, Idaho, Colorado, in arrow-shaped twinned crystals from the Broken Hill Mines in N. S. Wales, or in butterfly twins, or arranged in trusslike extensions from the same famous locality: the latter in heavy stout lemon-colored translucent crystals from Sardinia. In this section are found the rare carbonates of cerium, didymium and lanthanum, represented in *parisite* and *bastnaesite;* here too is *witherite* from Northumberland and Cumberland England in heaped up pyramids, with *strontianite* near it, glittering drusy surfaces from Westphalia.

MINERALS OF NEW YORK ISLAND

This list, abstracted from a paper by B. B. Chamberlain (Trans. N. Y. Acad., Vol. VII, No. 7), will give those locally interested in the study or collection of minerals a knowledge of the minerals found on New York Island.

Actinolite.	(Hornblende).	Apophyllite.
Adularia.	*Amethyst.*	*Aquamarine.*
Albite.	*Amianthus.*	Aragonite.
Allophane.	Analcite.	· *Asbestus.*
Alluadite.	*Anthophyllite.*	Autunite.
Amphibole.	Apatite.	Azurite.

Basanite.
Beryl.
Biotite.
Bornite.
 (Erubescite).
Bournonite.
Byssolite.
Calcite.
Chabazite.
Chalcopyrite.
Chert.
Chlorite.
Chromite.
Chrysoberyl.
Chrysotile.
Cleavelanditc.
Coccolite.
Copper Alum.
Columbite.
Crichtonite.
Datolite.
Dolomite.
Dumortierite.
Epidote.
Essonite.
Fibrolite.
Fluorite.
Fluocerite.
Galenite.
Garnet.
Graphite.
Grossularite.
Gypsum (Selenite).
Harmotome.
Heulandite.

Hydrodolomite.
Hypersthene.
Idocrase.
Iolite.
Jasper.
Jefferisite.
Kaolinite.
Kaolin.
Kyanite.
Laumontite.
Limonite.
Magnetite.
Malacolite.
Malachite.
Manganese (oxyd.)
Marcasite.
Marmolite.
Melanite.
Menaccanite.
Microlite.
Molybdenite.
Molybdite.
Monazite.
Mountain Cork.
Muscovite.
Natrolite.
Necronite.
Oligoclase.
Oolite.
Ophiolitc.
Orthite.
Orthoclase.
Phacolite.
Phlogopite.
Pinite.

Pyrallolite.
Pyrite.
Pyroxene (Augite).
Pyrrhotite.
Quartz.
Ripidolite.
Rutile.
Scapolite.
Sericite.
Serpentine.
Siderite.
Sphalerite.
Sphene.
Staurolite.
Stilbite.
Talc.
Tellurium.
 (Graphic).
Thomsonite.
Topazolite.
Torbernite.
Tourmaline.
Triphylite.
Tremolite.
Uraninite?
Vermiculite.
Vivianite.
Wad (Dendritic).
Washingtonite.
Water.
 (Chalybeate).
Wollastonite.
Xenotime.
Zircon.

PINK BERYL,
Pala, San Diego Co., Cal.
Bruce Gift, American Museum of Natural History

Development of Mineralogy*

It may well be imagined that at a very early period in the history of man the beauty of crystals and the range of colors in minerals must have attracted attention. So easily aroused are the senses by any strong appeal of external nature that the brilliancy of the quartz, the flash of pyrite, the dominant tints of agate, and the greens, reds, purples, and yellows of rocks could not long have remained unobserved. Industrial needs and the "house instinct," with its later architectural developments, soon led men to explore the mineral resources of the land, and to start in motion those useful and artistic studies that created metallurgy and sculpture. But, long before the quarries of Paria and Syene had been started, or the zinc beds of Laurium and the iron ore of Elba explored, the rude prehistoric races of all lands had consecrated to especial favor some sorts of stones and added the extreme exertions of their trained labor to increase their beauty. The polished and exquisitely shaped celt was made from those green stones which seemed very early to attain distinction with primitive people, and this color in jade, jadeite, saussurite, chloromelanite, and gabros, so extensively prevails in the ornamented or highly finished implements of the lake dwellers, the steatitic ollas of Californians and the New Zealand axes, as to lead many students to ascribe it to a peculiar constitutional tendency of taste among them. Mr. James Terry has said, "The 'color of spring,' which has been applied to jadeite and nephrite stone, seemingly has some inherent virtue in the eyes of barbaric and semi-civilized races."

Very early, also, differentiation in the nature, uses and properties of *stones* were made, and later the peculiarities of *minerals* afforded pleasure or suggested value to these archaic populations. In the mounds of the Mississippi Valley Squiers and Davis found sheets of silvery mica, blocks of glistening galenite, and lumps of hematite. Mr. Terry, in his exhaustive explorations in American archæology, has found in the Indian graves of southern California quartz crystals, single and terminated pellucid individuals, cut and polished amesthystine beads, and sinkers of magnetite, while the elegant and delicately chipped arrowheads of Oregon have been

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*The kind permission of the managers of the *Scientific American Supplement* was obtained for the use of this chapter, which originally appeared in that journal.

formed from the agate and chalcedony pebbles of the river beaches But it is much later, in the ages succeeding these earliest days of aboriginal culture, that mineral distinctions were clearly made, names applied to mineral species, and an exchangeable value put upon the inorganic products of the earth.

In China, India, Persia, Palestine, Egypt, Greece, Carthage, and Rome, we find an increasing knowledge, accompanied, in the case of Greece and Rome, with a fragmentary attempt at system. The gem stones, the ores, and industrial salts, naturally were first distinguished, and in China, from an immemorial antiquity, the jadeite or *Yu* stone possessed an almost sacred importance. The jadeite of China was elevated by their writers into an emblem of constancy and virtue; it constituted the most valued possessions of their mandarins, and three thousand years before our era received the affectionate workmanship of their skilled artisans. Sanskrit writers have recorded the knowledge of the diamond among the natives of India in very early times. The ruby and sapphire of Ceylon have entered into the decorations of native princes, and served for the embellishment of idols in Hindoo temples. The corundum mines of Upper Burma, where the ruby occurs in lime-stone, also in gem-bearing gravels, have been worked for centuries.

Among the ancient Jews precious stones appertained to their most sacred offices. We read in the St. James version the remark-able description of the breast plate of judgment (Exodus, chap. xxviii, verses 17-20), "And thou shalt set in it settings of stones, even four rows of stones; the first row shall be a sardius, a to-paz, and a carbuncle: this shall be the first row.

"And the second row shall be an emerald, a sapphire, and a diamond.

"And the third row a ligure, an agate, and an amethyst.

"And the fourth row a beryl, and an onyx, and a jasper; they shall be set in gold in their inclosings."

The rings of the Egyptians were mostly of gold and silver, but frequently their armlets and bracelets were inlaid with precious stones (see Exodus xxxv), and among these were lapis lazuli, red and green stones of undetermined natures.

Wilkinson ("Ancient Egyptians") says: "The scarabæus itself was of green stone, carnelian, hematite, granite, serpentine, agate, lapis lazuli, root of emerald, amethyst, etc." The arts of Chaldea seem to have scarcely employed mineral accessories, and Rawlinson says there is found in their art relics no silver, zinc, or platinum; only gold, copper, tin, lead, and iron. Assyria seemed also to have used stones in its arts infrequently. Of Babylonia

Rawlinson ("Ancient Empires") contains the following instructive and suggestive paragraph:

"It may be doubted whether any gems were really found in Babylonia itself, which, being purely alluvial, possesses no stone of any kind. Most likely the sorts known as Babylonian came from the neighboring Susiana, whose unexplored mountains may possess many rich treasures. According to Dionysius, the bed of the Choaspes produced numerous agates, and it may well be that from the same quarter came that 'beryl, more precious than gold,' and those 'highly reputed sards,' which Babylon seems to have exported to other countries. The western provinces may, however, very probably have furnished the gems which are ascribed to them as amethysts, which are said to have been found in the neighborhood of Petra, alabaster, which came from near Damascus, and the *cyanus,* a kind of lapis lazuli, which was a production of Phenicia. No doubt the Babylonian love of gems caused the provinces to be carefully searched for stones, and it is not improbable that they yielded besides the varieties named and the other unknown kinds mentioned by Pliny many, if not most of materials which we find to have been used for seals by the ancient people. These are carnelian, rock crystal, chalcedony, onyx, jasper, quartz, serpentine, syenite, hematite, green feldspar, pyrites, lodestone, and Amazon stone."

In the industrial needs of early civilizations the efforts to extract from the earth its most useful metals brought men in contact with the mineral associations of metalliferous beds and veins, and in this way probably the more extended acquaintance with the stony contents of the earth's surface arose. The turquois, however, in Persia, exerted a strong attraction for the inhabitants and was probably mined for its intrinsic beauty from a narrow vein in a trachitic rock. Among the Aztecs Prof. Blake believes that the turquois possessed a pre-eminent value, and he refers the famous designation "chalchiuitl" to this mineral. From such casual reminders we are led to surmise that a moderate acquaintance with the more prominent minerals of the earth was acquired long before the subject was approached in a systematic manner by writers. This knowledge became disseminated through commerce among nations and the Phenician sailor became a substantial factor in bringing about the first attempt at classification, by not only adding to the information acquired, but by giving it a wider acceptation.

The vigilant Phenician navigators in the active search for metallic wealth established trading stations along the shores of the Mediterranean Sea; they also visited the silver mines of Spain,

the lead mines of Brittany and the veins of Cornwall and presumably the amber beds of the Baltic. Their artisans in Tyre and Sidon excelled in workmanship and they furnished to King Solomon the assistance he needed in the preparation of the temple. But perhaps no attempt, which assumed the character of a scientific examination, was made to classify and enumerate minerals until the time of Aristotle and his pupil Theophrastus, in the fourth century before Christ. The extent of their work is very partially known, but may have been in part reincorporated in the works of the physician Dioscorides. Among the remains of classical antiquity the works of Pliny the Second are the most exhaustive and pretentious in their treatment of natural history. In the famous books which have come down to us we have a rambling dissertation on all subjects of human knowledge, as then developed, in which the aspect, inhabitants, and products of the earth are involved. In the thirty-sixth and thirty-seventh books, stones and gems are taken up and their discussion is richly garnished with tales, fables, and historic incidents. It is impossible to discern anything but the most superficial method in their arrangement, and of course little or nothing more could be expected.

The processes of chemistry, the laws of crystallography, and the optical properties of minerals were then unknown, unsuspected, and the classification depended upon what is extracted in metal form from natural earths, or minerals, what industrial or medical uses they subserved, and their color, hardness, texture, etc.; in short their natural appearance and behavior. These three points of reference outlined the classification of minerals so far as the ancients possessed any classification at all, and it, of necessity, led to confusion and error. A few references, freely translated, from these notable essays of Pliny, are of interest, and serve to emphasize the partially childlike condition of natural science in his time, and the peculiar mixture of conceptions derived from organic with the facts of inorganic nature. This condition of science prevailed long after Pliny, and assumed a semi-metaphysical character in the middle ages, and was not entirely eliminated even in the days of Linnæus.

After a long chapter on marbles, their uses, varieties, and the celebrated structures or beautiful statues made from them, with incidental expressions of alarm and regret that luxury among the Romans had reached so great a height, our author continues: "Leaving marbles for the marvelous characters of other stones, who would hesitate to place the magnet in the first place? What more wonderful or where a greater perversity in nature! She has
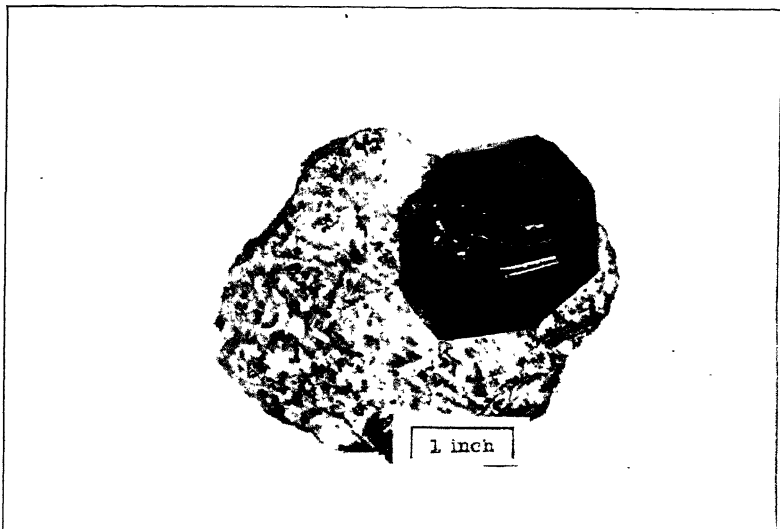
GARNET
Avondale, Pa.
Bement Collection, American Museum of Natural History
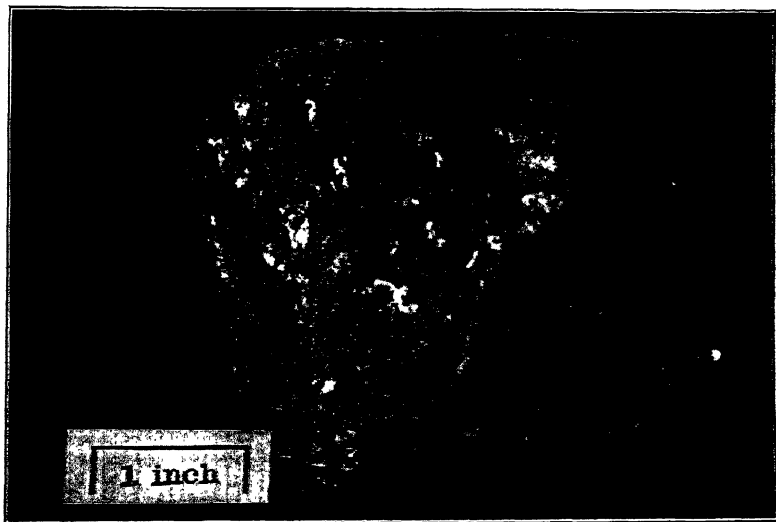
VESUVIANITE
Magnet Cove, Ark.
Bement Collection, American Museum of Natural History

given a voice to stones, or we may say, answering man, truly speaking back to him. What harsher than the rigidity of stone? Lo! she has given to it sense and hands. What more unyielding than the hardness of iron? But it yields and undergoes discipline. For it is drawn by the magnetic stone, for that material, dominator of all things, runs to the viewless power, I know not what: and as it comes nearer, it is lifted, is held, and adheres by an embrace. On account of this they call the *siderite* by another name, the Heracleon* stone. Discovered in Ida, it is called by its author *Magnes*. It is found everywhere, as for instance in Spain. It is said to have been found adhering to the nails of the shoes and the spike of the shepherd's crook, when he pastures the herds. Sotacus showed that there were five kinds of magnet. . . . The first difference was in their male and female principles, the second in their color. For what is found in Macedonia is red and black, but the Bœotian sort has more red than black color. That which is found in the Troad is black and of the feminine sex, and therefore lacking in strength. The poorest is in Asia, shining and not drawing iron, and like unto pumice. The best are more blue. The Ethiopian variety is most praised, and is exchanged for silver. There is also found hematite, a *magnes* of red color, which rubbed gives off a bloody tint and also a saffron. In attracting iron there is not the same nature in hematite as in *magnes*. All these are good medicine for the eyes, each in its proper measure, and especially they stop a running of the eyes. Burnt and crushed they cure burns. Again there is another mountain in this same Ethiopia, not far off, which produces the *theamiden* stone, which repels and drives away iron."

Pliny speaks frequently of the medicinal properties of minerals; and the ochres and iron stones, with so-called schist, seem to have served very curious medical uses.

Hemorrhoids, burns, weakness of the eyes, liver troubles, blood diseases, were treated with preparations of these natural earths, some of which may have been in part vegetable in their origin and nature. The eagle stones, familiar to collectors as limonitic concretions holding pebbles and commonly inclosing a quantity of white sand inside of a ferruginous rind or crust, are alluded to by Pliny. The passage occurs in the thirty-ninth chapter of his thirty-sixth book. He says they are found in the nests of eagles, and that it is reported that there are always two, male and female, but that of these stones there are four kinds. Those from Africa are small, soft, friable, holding within them white smooth clay. These he considers feminine in sex; whereas the male sorts are hard, reddish, and inclose a hard pebble, and are found in Arabia.

*Heracleon had the significance of adhering.

The third came from Cyprus and are spherical, inclosing sand and stones. The fourth, called Taphian, came from the mountain Taphyes, and were there taken from streams, shining and round in appearance. Parturition was prevented by these stones. A glance at Pliny's treatise on gems is of interest, and in connection with the foregoing gives some impression of the crude, inchoate, and purely artificial condition of mineralogical science in his day.

PLINY'S BOOK ON GEMS.

At the outset our author rehearses the many qualities of gems which have attracted men and placed them among the choice and unattainable products of nature. He attributes this violent flame of admiration for gems to their use in rings, and alludes to the old story of Prometheus wearing in an iron ring upon his finger a fragment of the rock to which he was or had been chained. He tells the fable of King Polycrates, whose unfailing fortune awoke in him fears of some overhanging calamnity, and who to avert Nemesis threw a precious gem-bearing ring into the sea, which was again returned to him in the belly of a fish, which from its great size had been considered worthy of the royal kitchen. He alludes to the agate of Pyrrhus, upon which plastic nature, not art, had impressed the group of the nine Muses and Apollo holding his harp, while the *insignia* of each Muse was appropriately reproduced.

Gems were, he says, at a very early period cut, and we learn that the great Alexander forbade any stone to be engraved with his face unless the work was executed by Pyrgoteles, an accomplished workman, and who was succeeded by Apollonides and Cronius in the glyptic art. This art soon rose in importance, its professors were highly esteemed, and their workmanship offered to the gods, and in this way the nature, properties and features of gem stones were more closely studied and their localities more constantly recorded.

Murrhina, which Pliny first mentions in connection with the wine vessels of Nero and Pompey, is our chalcedony, the amorphous form of quartz. He alludes to its origin as a condensation of moisture by heat, under the earth, a physical conception which would appear particularly erratic to the youngest students of today; he mentions its variety of color, with distributed spots in the pervading purple, now assuming the appearance of "ruddy milk" and now putting on the color of the rainbow.

Crystal, our quartz, elicits a further physical theory as to its apposite origin from moisture congealed by extreme cold, and this supposition seems warranted to Pliny, as he says "it certainly

is nowhere found other than in those places where the rigor of winter snows prevails; certainly it is ice (glaciem), whence the Greeks derive its name."

Among many localities he mentions the Alps of Europe, which have to-day furnished such large and splendid specimens. He notes its occurrence in mountainous regions, its deportation from eminences by mountain torrents, and quotes Sudines as averring that it arises (nasci) only in places having a boreal position. He is puzzled over its six-sided form, for which he fails to find any explanation, all the more since these angular summits are not always alike, and have faces smoother than any artist could impart. The largest quartz seen by Pliny was one which Livia Augustus dedicated to the Capitoline Jupiter, of the weight of fifty pounds. He enumerates the defects of quartz, as its ferruginous roughnesses, cloudy spots, hidden or interior "tumors," red rust (rubigo), and chinks resembling the finer rootlets of plants.

· Amber (succinum) follows quartz as a natural product devoted to luxurious uses. Its mythical origin in the tears of the sisters of Phaeton, who were turned into poplar trees by the bolt of Jupiter, or as an exudation from trees on the Adriatic at the rising of the Dog star, points conclusively to a recognition of its resinous and vegetable character, while the curious fable of Demostratus that it pertained to the urine of the lynx, indicates also the belief in its organic nature.

Sotacus, however, credited it to certain rocks in Brittany, from which it escaped—the *electrides*. It was then traced to northern Germany in the Baltic, from whose depth it had been thrust by storms upon the land, and was called "the purge of the solidified (concreti) sea," while other philosophers referred its origin to the vehement action of the rays of the setting sun, which hardened the "unctuous sweat" (pinguem sudorem), which, escaping to the sea, was returned by storms to the land.

Numerous localities for amber are given, and to many some peculiar fable was attached explaining the source of this fossil resin. The Garden of the Hesperides, for instance, dropped it in a swamp, where it was collected by the Hesperidae, while the poet Sophocles perpetuated the legend of its being the tears of the Meleager birds, a fancy that Pliny scores with a sharp expression of contempt.

But Pliny expresses firmly for himself the conviction that electrum (amber) arises from the "dropping marrow of a tree of the pine kind, as gum in cherry trees and resin in pine;" that it is congealed and carried by storms into the sea, whence again it re-

appears upon the northern shores. He attributes to it, as usual, medicinal properties, resisting tonsilitis and troubles of the jaw, and such ailments (goiter?) of the neck as arise from drinking certain waters; also fevers, obscurity of the eyes, and deafness. He alludes to a mass weighing thirteen pounds. Pliny separates the ambers into varieties according to color and surface. He alludes naturally to its electric properties, "for being rubbed by the fingers it receives the animation of warmth and draws unto itself straws and dry leaves such as are light."

Pliny discusses *lyncurium,* of which Theophrastus before him had written, "equally wonderful is the lyncurium (for out of this signets are made) ; it is hard, it attracts as amber; it is the hardened urine of the lynx; it is found by digging; . . . for the animal endeavors to conceal the deposit by scraping up the earth after voiding."

Pliny treats all this increduously and refers lyncurium to amber. King, however, says "there can be no doubt that the gem described by Theophrastus is our jacinth (zircon), the yellow jargon, distinguished by having for its chemical base the earth zirconia, peculiar to this family."

Pliny assigns to the diamond the same eminence it possesses to-day. It is the *adamas* of the ancients. He also attempts a classification of its varieties and mentions six. As he has observed the hexagonal form of quartz, he also describes the crystalline appearance of the natural diamond, how it appears "with six angles, polished faces, finished in a point, or pointed at opposite extremities, as if two whip-tops were united by the broadest sides."

He mentions its extreme hardness, resisting the blows of hammers, its inertness to fire (ignium victrix natura), and contributes an excellent description of four kinds of diamonds: the Indian, not found with gold (he has just before alluded to the association of the diamond with gold), but similar to *crystal* (quartz) ; the Arabian, smaller; the *cenchros,* like a millet seed; the Macedonian, found in the gold mines of Philippi, equal to a seed of mustard. After these he mentions the Cyprian, of a blue tint, efficacious in medicine, and the *siderites,* steely in splendor, and heavier, yet differing in nature, "for it can be broken by blows, and perforated by the other adamas." These last two varieties have been regarded as sapphires. Pliny attributes many virtues to the diamond; it corrects poison, keeps away madness, expels vain fears, and, as to its infrangibility, if steeped in goat's blood, it can be broken.

Pliny exults with a connoisseur's fervor over the delicate and deep shades of emerald. It alone of gems fills the eye, neither

WILLEMITE
Sterling, Sussex Co., N. J.
Bement Collection, American Museum of Natural History
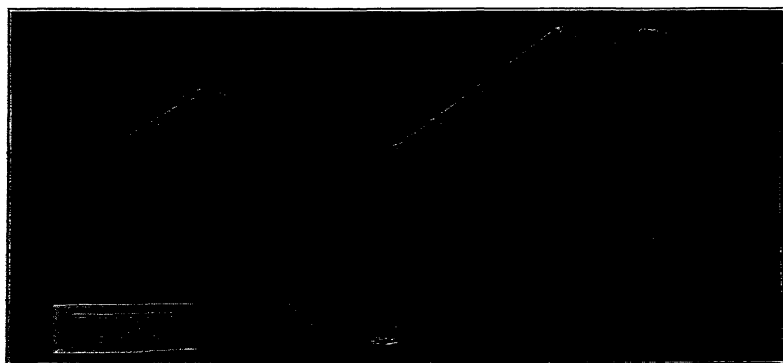
WILLEMITE
Sterling Hill, N. J.
Bement Collection, American Museum of Natural History

tires. He insists that the eye wearied of other study is refreshed by the aspect of the emerald, which overcomes its lassitude by its "lenient verdancy," that it remains unchanged in sunlight, in shadow, translucent even when thick, as is the quality of water. Pliny attempts to separate twelve varieties, but it is admitted that most of these were plasmas, malachite or chrysocolla. Old authors have held that the ancients were unacquainted with the emerald, but, as King maintains, such keen and adroit recognition of the characteristics of the gem as shown by Pliny leaves little doubt that he was discussing this mineral.

As a matter of fact, we know that the ancients possessed this gem, though it was regarded for a long time as unknown previous to the discovery of America, and the Scythian stones first mentioned by Pliny, may have been derived from the Ural or Altai mountains, which have in recent times furnished emeralds. Pliny mentions the Bactrian, "which were said to adhere in the crevices of rocks during the Etesian winds. Then they shone upon the ground, because by these winds the sands were greatly stirred."

The Egyptian, which have been assigned to the region about Mount Zubara, where, as King remarks, are extensive abandoned workings from which the ancients may have obtained this material, though late investigations have failed to uncover any specimens. The other eight kinds Pliny refers to copper mines, from which it has been inferred that he spoke of prase, malachite, chrysocolla, and possibly turquoise.

Pliny, with his extreme sensitivity to visual effects, points out in these stones, white cloudlets, spots, foreign bodies, dullness in sunlight, coppery tint, absence of true greenness, loss of color by age and in the sunlight, and complicated mimicries of natural objects.

It was indeed the first step toward classification, and where no means were supplied for attaining a knowledge of the inner constitution of minerals, either as chemical or physical aggregates, these superficial appearances, as color, etc., and more obvious properties, as hardness, were alone relied on by the observer. Pliny called *chalcedony* a chrysocolla(?) which he ingeniously describes as fragile, of uncertain color, and resembling the changing tints of the moving neck and tails of peacocks and doves, while *inclined* it appeared more or less translucent, veined and spotted. He may have had in mind something quite different, and the *chatoyant* effect might be referred to some feldspar.

Pliny referred the beryl, with excellent judgment, to the emerald (smaragdus), and speaks of its six sides, its length, alludes to its yellow tints (chrysoberyl, chrysolite), with paler varieties called

by him chrysoprase, a fourth form hyacinthizontes, and fifth aeroides, which was blue, and by some commentators is regarded as the sapphire, though the contrast in hardness would hardly have escaped the quick appreciation of Pliny. Indeed, it might more probably prove to be a blue topaz, itself scarcely removed in hardness from some of the more dense beryls.

Finally Pliny separates the waxy, colorless, and oily colored beryls, exhibiting here as elsewhere, his certainty of ocular criticism.

The opal appeals to Pliny's best mineralogical instincts, and he has left us an unexcelled description of its ardent beauty. "Made up of the splendors of precious stones, it is unspeakably difficult to describe it. In it is the tender fire of the carbuncle, the shining purple of the amethyst, the sea-green of the emerald, all shining in an incredible mixture. Some with the greatest access of luster equal the colors of painters, others the fervid flames of sulphur, or fires quickened with oil."

He speaks of the defects of the opal, as when its color declines into heliotrope, or it is pale, or presents flaws, or specks meet the observing eye. He mentions its successful counterfeiting, and indicates as a test of quality the scattering radiance of the stone as it is moved hither and thither. He speaks of their being found principally in India, but also in Egypt, Arabia, Galatia, Thasos Pontus, and Cyprus.

The onyx and sardonyx are mentioned by Pliny and their home given as in India. The former was three-layered, white, red, and black, and the latter separated into fiery, black, corneous, and veined varieties, while this attractive description of the onyx is worthy of notice:

"The true onyx possesses many and white zones with veins, which mingle with a transition of colors quite indescribable, yet returning into a single combination of grateful beauty."

Pliny knew of the many shades of garnet stones, and under carbuncle describes them with success. He says: "In all sorts the masculine are more splendid, the feminine was more dull. In the male gems some are seen of a liquid brilliancy, others black, certain ones pale, and some flashing more in the sun.

The best are the *amethystizontes,* that is those of which the fire expires as it were in the violet of the amethyst. Next to these come those called *sititas,* shining with an interior refulgence. They are found everywhere, revealed by the reflection of the sun.

Satyrus says the Indian stones are not clear, many being turgid and of a gloomy luster. The Ethiopian stones are fat, not emit-

ting light but burning with a concealed fire. Callistratus is of opinion that the fire of the carbuncle should be white, nebulous at a distance, if near at hand gleaming brilliantly. On this ac·count, by many this carbuncle is called *candidum*. Those of India, which shine more dimly and lividly, are called *lithizontes*. The Carthaginian are smaller, barely equaling one-sixth of the Indian gems.

Archelaus says the aspect of the Carthaginian to be darker, but when turned to a flame or the sun to be more vividly excited than others. The same in the shade is seen to be purple, under the open ruddy, flashing back the rays of the sun. Among the Carthaginian the male gems shine with a starlike interior flame, the females diffusing a universal light beyond themselves. The alabandine are blacker and more defective than the rest."

Pliny speaks of artificial garnets and points out means for their detection. Besides the above varieties of carbuncle (garnet), he instances the garamantic, found in India and Arabia, of which the highest praise was found in the notice of golden drops shining deeply within it, and imitating the heavenly disposition of the Hyades; on this account valued by the Chaldeans.

Pliny's "topazius" is regarded as a distinct stone from the modern topaz, and has been referred to as *peridot* or *chrysolite*. Pliny alludes to its being found upon an island in the Red Sea, of which Diodorus Siculus gravely tells us that it abounded in this gem, whose brilliancy was outshone and deadened by the sun, so that its collectors looked for it at night, when it was conspicuous. The centers of light thus revealed were covered over and the rock, with its attached treasure, cut out the succeeding day. The identification with the peridot would admit of doubt.

The *callais* of Pliny is considered our turquois, though King argues for its reference to a variety of chrysolite, on the ground partly of its green color, and because of Pliny's expression "full of holes and dross." an incongruous description, if applied to an opaque solid like tourqoise. Here, as elsewhere, Pliny displays a delicate discrimination in color, and a gemmist's sense of decorative accomplishments in alluding to the reciprocal charm gained by this stone and gold in conjunction.

Pliny then enumerates other stones distinguished by their green color, as prase, chrysoprase, green jasper. He notes variations in their color, how they decline into yellow tints and are marked with blood spots (heliotrope), and finally gathers together a series of contrasted stones under the generic appellation of jasper, as emerald green, azure blue (aerizusa), blue, snowy, purple, cloudy,

turbid (chalcedon), violet; stones which may be regarded per-
haps as varieties of silica, such as we are accustomed, under jas-
per, chalcedony, quartz and amethyst, to find exhibiting numer-
ous tints and phases of aggregation.

The amethyst, indeed, is by Pliny specially designated and, as
is his manner, divided into five groups distinguished by color, the
imperial purple, the hyacinthine, a lighter tint, the wine colored
and the pale crystals. He gives pre-eminence to those which, be-
ing held aloft, reveal a "rosy light shining gently in the midst of
the purple." Such gems the magi believed resisted inebriety and
properly inscribed with the name of the moon or sun and sus-
pended from the neck on the hairs of a dog or the feathers of a
dove, overcame venom.

The *hyacinthus* of Pliny has been referred to the sapphire,
since Pliny avers its relationship to the amethyst, "differing, in
that the violet glory shining from the amethyst is diluted in the
hyacinth." The *lyncurium* of the ancients was the modern hyacinth.

Referable also to our hyacinth (zircon) may be Pliny's *chryso-
lectrum, leucochrysum,* and *melichrysum.* The property of aster-
ism is noted by Pliny, with a probable confusion with the allied
phenomenon of diffraction called *cat's eye* or moonstone. He
speaks expressively of the "inclosed light like a pupil which is
emitted with the tilting of the stone, and, as if oscillating, moving
from point to point, and placed opposite to the sun, returning its
rays." He indeed speaks of a stone (astrion) found in India
which "within from a center like a star shines with the splendor
of a full moon," a very suggestive and satisfactory description of
adularia.

Agate receives from Pliny a series of synonyms, each name
expressive of a peculiarity in the color, shape, or markings, which,
as every one knows, attains the last degree of mimetic variations.
To the agate the Persians attributed the greatest potency. It
cured the bites of scorpions and spiders, assisted the eyes, quenched
thirst, averted storms, and repelled thunder, if strung on the mane
of a lion.

In this connection Pliny mentions a number of fabulous stones
which the superstitious practice of his time invested with miracu-
lous virtues. Such were the *alectoria, androdama, argyrodama,
antipathes, arabica, aromatites, batrachites* (toad stones), etc., a
long obscure list, with a cloud of mythical fancies attached to
them; while their origin in the stomachs of birds, or beasts, in
the fading light of the moon, etc., their power to reproduce gems,
to allay winds, kindle fires, overcome the strategy of savages

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(*hematite*), and work successful charms, or endow with rare gifts of mind and person their wearers—all constitute a singular and graphic portraiture of the traditional lore attached to stones and the inherent tendency of the primitive mind to necromancy and superstition.

Pliny concludes his remarkable essay with observations upon the imitations of gems, coloration of stones, and their preferable forms in nature, and some rules for their detection.

The thirty-seventh book of Pliny's "Treasury of Knowledge," in the first century, forms a capital presentation of the state of mineralogical science in that early day. Taken in connection with his work on stones and ores, it shows us how eagerly the eyes of men had surveyed the earth's surface and to what extent, guided by their uses, their most obvious physical characters and their colors, the barely emergent science of mineralogy had progressed.

Many distinctions which we now retain had been made, a number of names persistent to-day applied, and a faculty of criticism or observation aroused. Pliny's work represented the consolidated wisdom of his time in mineralogy, as he was himself the heir of all previous mineralogical study, and this book justly may be regarded as the initial effort at a system and text book of mineralogy.

The Arabians fostered learning, and from the East invaded occidental Europe with the heritage of Grecian speculation. They became the schoolmen of the continent, and enlightened the Christian schools in the rudiments and methods of astronomical and medical science.

Their zeal in philosophy, their spirit of acquisitive curiosity; and their keen application, soon gave distinction to their academies, and extended the influence of them far beyond the limits of the Moslem realm.

Among these Avicenna (Ibn Sina), born in 980 and dying in 1037, contributed to the expansion of mineralogical science, or at least kept alive the interest in scientific studies, from which, in its general aspects, mineralogy received a subordinate return. He was an Arabian physician, learned in the books of his time, in Aristotle, Euclid, Ptolemy, Galen, and animated by that thirst for knowledge which then appeared so strenuous among the Arabians.

It impelled him and his great successor, Averrhoes, to traverse the field of human knowledge as then developed, and envelop their own speculations in the dress of that pseudo-scientific pretense to system which was the heritage of science from the classical period. At twenty-one he prepared an encyclopedia in which was reproduced all that he had read.

His works are mostly medical, but there appears in them references to natural objects, and as many of the ordinary oxides were themselves useful in medicine, some narration may be found in his books concerning their localities and properties ("De Tinctura Metallorum, Declaratio Lapidis Physici").

In his "Conglutinatione Lapidum" geological science in some of its most prominent principles receives a singularly perspicuous definition, as in the origin of mountains, and the influence of acqueous erosion and deposition.

Averrhoes (Ibn Raschd) was born in 1120 and died in 1198. He exceeded in intellect his predecessor, and displayed a broader philosophical temperament, without as much acuteness of perception. He was deeply versed in Aristotle, and prepared an elaborate commentary and abridgment of the great pagan thinker. In "De Substantia Orbis," he treated of the texture of the earth and gathered together the utterances of his predecessors.

The contributions to the development of mineralogical science of these distinguished Arabians, whose fame perhaps very much exceeds their merit, was more felt in its temperamental than its positive character. They kept alive science and so facilitated the growth of observation and of the spirit and enthusiasm for natural investigation.

In the sixteenth century appeared at Lubec, and subsequently at Leipsic, the famous metrical essay on gems in Latin, by Bishop Marbodus, Bishop of Rennes, written in the eleventh century. This curious production, which incorporated the various picturesque legends which time, fancy and superstition had associated with precious stones, was utterly devoid of scientific importance. The pages of Pliny supplied much of it, and the writings of Isidorus, Bishop of Seville, who, in 630, wrote on precious stones, were also poetically reproduced in its rather listless and mechanical lines.

The poem claims an earlier origin in the work of Evax, King of Arabia, who wrote to the Emperor Nero on the subject of stones, their names, colors, localities, abundance, and potency. It certainly has considerable antiquarian interest, and embodies that childlike and wondering element of thought which invested, in those credulous days, every fable with importance, and every object of value with magic.

The writer ventures, in rather free doggerel translation, to introduce the reader to some portions of this "Lapidarium," so far at least as to enable him to realize the mineralogical "point of view" of that early time.

Of jasper our melodious lapidary sings;
Ten and seven species of jasper are found,
Differing in color all the world round;
Hither and thither over the earth,
The green and translucent are best in their birth;
Worn chastely, fevers and pestilence fly,
And women in childbirth are helped thereby.
'Tis believed to bring safety, and as it is writ,
Expels the black fancies which o'er the mind sit;
While furnished with silver, around it enframed,
'Tis most potent to help the sick and enchained.

Sapphire—whatever may have been exactly indicated by sapphirus—is thus distinguished for its abundant talismanic qualities:

Sapphire, of gems, most apt for royal eyes,
Gloriously shining, most like the azure skies,
Inferior to none, in virtues and in beauty,
Is called by many the Stone of the Systites;
Since mixed with Libyan sands in wild confusion
'Tis found, by driving waves on beaches in profusion;
Though that most sovereign which the Medians bear,
Which yet, opaque, should lesser honors share.
This stone by potent Nature well endowed
Is sacred called, and gem of gems allowed;
For this the human body young it keeps,
And he unbrokenly who wears it sleeps.
Envy it overcomes, and by no terror shaken
Bolts it unlocks, chains breaks, and prisoners awaken.
It soothes the gods, and brings response to prayer,
'Tis said for reconciliation, good to bear.
And still more dear Cynthia loves this gem,
And grants to all who wears it her amen!
For corporeal ills this stone is ample cure.
The fever's flame its coldness cannot endure;
It brightens still the eyes, removes the ache
Of listless head, and mixed with milk, the ulcerous cake,
While stumbling tongue it helps to speak;
But he who wears it chaste must keep.

Two more examples from this unique work may suffice to gratify the curiosity of the reader or perhaps furnish him inducements strong enough to read the original poem, which, in spite of its utter dearth of sentiment, is curiously interesting.

The first extract is a description of beryl, in which at the outset its six-sided (hexagonal) form is alluded to, and the second refers to the tradition of the glacial origin of quartz, with an expressed doubt whether this time-honored inference is unexceptionally true.

> Conspicuous the six-angled stem reveals
> The beryl; which, unless colorless, conceals
> A violet tint, or else the sea-green wave
> Seems shining there, as seen within a cave.
> This stone from India comes, a token,
> 'Tis said to help the love of married men.
> Though they that wear it fall to boasting,
> And tightly squeezed the hands seems roasting,
> The water that laves its sides wherein it lies
> Will bring refreshment to ailing eyes.
> Or drunk, will quickly all the lungs renew
> And cure the troubles of the liver too.

The lines devoted to quartz (*crystallum*) are as follows:

> The crystal hardened by long-enduring cold,
> As some have written, other sagely told,
> Still to our eye reflects the color of the ice,
> Though this is doubted as a fact precise.
> Since, so they say, in warmer climates too,
> The rock crystal with equal beauty grew.
> Yet this is fixed, nor mixed with doubt,
> That when against the sun 'tis turned about,
> It conjures fire, and dry weeds enflames,
> This is most clear, and chief among its claims:
> And also mixed with honey by matrons used,
> The breasts with milk are then suffused.

For the most part, this celebrated poem confines its treatment, as might be expected, to those associations with gems and valuable stones which recall their virtues in sickness, or peculiar subtile, emanations, whose efficacy their owners derived from wearing them.

Many stones are mentioned whose identification are extremely doubtful or impossible, as the *Galactida,* the Medean stone, *Chelonitis, Orites, Hyaenia, Enydros, Pantheron, Apistos,* and others; obscure mineralogical aggregates, or stones perhaps, which in some cases obtained distinction from their water-polished surfaces or chance brilliant coloration.

In the twelfth century Mohammed ben Mansur prepared an elaborate treatise on stones in which his own observations were

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plentifully incorporated. This was followed by the writings of Albertus Magnus, who living in the thirteenth and fourteenth centuries, first insisted on the importance of form and began those speculations as to the origin and essential substance of minerals which brought him into reflections upon the crystalline condition and fixed constitution of mineral species.

He wrote ("De Mineralibus et Rebus Metallicis") "it is therefore certain that stones (minerals) have fixed forms and species. These forms are not spirits, for life is essential to spirit. If they make use of nourishment, they should be provided with porous avenues through which such nourishment might be merged, assimilated in them. Neither is it conveniently considered, since the spirit of a stone may then be oppressed by terrestrial inclosure, and thus unable to exercise life and sense, as many physiologists aver, since their nature would be deficient in necessary parts by not giving organs to stones, by which she should expedite their necessary operations. Stones therefore have not spirits, *but they have substantial forms endowed with celestial virtues and a commixture of proper elements."*

Here we discern the glimmering or awakening of thought in relation to the nature of minerals. They were no longer inorganic groups of physical qualities, accidents of location, or partial reflections of human definitions. Their interior state, the individualizing power, influence, or constitution which they represented, began to force itself upon speculative minds, and so dawned the metaphysical era of mineralogical science which, in conjunction with the growing popularity of alchemy, retained the science in a quasi-grotesque phase of poetical and chimerical invention.

The ripening spirit of scientific investigation received a fresh impulse from the enthusiasm and learning of George Agricola in the sixteenth century. He was a man of marvellous acquisitions. All the knowledge of his time, all the inherited wisdom of previous ages, with their speculations and vagaries of thought, were known to him. He was finally a critical mind. He weighed carefully his conclusions, and so became the real pioneer in the creation of a mineralogical science which began to reveal some of the features which characterize it to-day. E. Lehman, his translator, says of him: "He was the first in modern times who reflected upon mineralogical subjects with perseverance, unprejudiced judgment, and fairness, and wrote with Grecian elegance." He discussed the geognostic problem of the earth's surface, the character, nature, and processes of volcanic action, the features of fossils, the circulation of the atmosphere.

He studied the movement of water, its geological and chemical activity, its physical properties; he wrote upon air and heat, the currents of the air, their causes, upon earthquakes, their kinds, upon the origin of mountains, upon mining and peculiarities and changes in fissures, vein matter, etc., upon mineral earths in their general relations, their origin and character, upon the features of stones, their formation and their physical features. He brought into notice, in their relation, besides the color, taste, odor, luster, hardness and transparency of minerals, their density and gravity, their roughness and smoothness, etc.

His treatment of these subjects is somewhat pedantic and scholastic. He introduces a subject, as water, gives some proposed explanation of its occurrence, accompanied by proofs, these in turn he overthrows, then follows a second interpretation of the phenomenon, considered with new arguments for its support, which are, in turn, destroyed; the series of alternating propositions with their appropriate discomfiture being concluded by his own hypothesis, which naturally remains unchanged, *nem. contrad.*

He adopted the division of the four principal elements in minerals as the earthy, saline, ignitable and metalliferous. The term fossil expressed all the mineral contents of the earth's crust, without reference to their organic origin.

He separated these mineral sections into groups; as under earthy, the siliceous, argillaceous, barite-bearing, talc-bearing, calcareous; under the saline, cooking salts, sulphur salts, etc.; under the ignitable, coal, graphite, bitumen, etc.; under the metallic, the argentiferous, auriferous, etc. These divisions were again broken up into subordinate generic (specific) heads; as under quartz he placed rock crystal, chalcedony, amethyst, while again, according to their quality (Sippschaft), these varieties are still further dissected, as in amethyst, the common and dense.

Here was classification enough to satisfy the systematist. Already the chemical initiative, introduced through alchemy, had revealed the chemical character of many compounds; mineral species had increased, and we begin to recognize in the pages of Agricola the growing complexity and expansion of the science and its widening nomenclature.

Agricola had noticed the varying crystalline forms of minerals, how many possessed angles, some had triangular faces, others were cubic as pyrite, while the modifying secondary planes about the terminal pyramids of quartz excited his wonder. He averred that minerals, especially crystals, had been formed from a pure liquid solution.

Hieronymus Cardanus in 1663 wrote upon the nature and forms of minerals, especially of gems. It was gems whose conspicuous beauty, distinctions in color, and crystalline individuality from the first attracted attention and afforded grounds for speculation.

Cardanus wondered over the six-sided forms of quartz (crystallus). He suggested that it might have arisen, as did the hexagonal form of the bee's cell, from the surrounding and reciprocal pressures of spheres, but abandoned this physical explanation and assumed an implanted force which expressed itself in length and breadth and depth in such a way as to give six sides to quartz, and related hexagonal minerals, as beryl, a view which was ridiculed by his opponent, Scaliger.

Christopher Eucelius continued the publication of observations upon the mineral contents of the earth which he had seen, and, as with Agricola, made most of his notes upon the minerals of mining regions.

It was the industry of mining which in the rise of German mineralogy played an important part in eliciting the attention of students of nature for the inorganic products of the recesses of the earth.

Eucelius noticed the regularity and persistency of crystals, and expressed his admiration of the activity of nature in the depths of the earth (*Adeo non ociosa est natura, ipsis in terrae visceribus, ipsis in tenebris*), where "she displayed her geometrical power" in these crystallized masses, and where, too, as he says, he had seen the impressions of little fishes, and the "traces of lions and wolves."

Crystallography in its adaptation to the study of natural forms received an important impulse from Wentzel Jamitzer, who prepared 140 models of geometrical forms, in which the simple forms were abundantly modified and were grouped in composite multiples, so as to suggest twinning and trilling.

Caesalpinus, Gesner, Kentman, living at the end of the sixteenth and beginning of the seventeenth centuries, attempted to reveal the secret of crystallization. The first artificially prepared alum, saltpeter and sugar crystals, and said of quartz, which from its universality and perfect crystallization challenged attention, that it had been formed from the purest substance, and so in its six-sided form more nearly approached the circle, which might be regarded as the perfection of form and most expressive of the purest liquids.

He imagined the terminal pyramid of quartz was produced by deficiency of material for the continuation of the prismatic faces, and that it was more clear and less contaminated than the rest of

the crystal, in which, as it were, the dregs of the solution settled. Gesner pointed out irregularities in the angles and faces of quartz, and Kentman observed and described natural crystals.

Peter von Arles imparted some of the mediæval romanticism to his conceptions when he assumed, at the beginning of the seventeenth century, a correspondence between the seven metals, the seven precious stones and the seven planets. The moon symbolized silver and quartz.

Of the form of quartz he speculated as follows: "When the earthy and supernatural matter separated itself from water, it (the matter) struggles in every part to consolidate itself, and lines (radii), as if drawn from some central point, appear to shoot outward toward the circumference. But, as they (the lines) meet opposing lines, they cannot complete a circle, but only (through peripheral impact) form a six-sided figure." (*Sympathia septem metallorum ac septem selectorum lapidum ad planetas.*)

The distinguished Anselmus Boetius de Boot wrote in his "History of Gems and Stones" that the formative principle in minerals was a lapidifying power. Matter separated from solution through withdrawal of heat was drawn into angular shapes, and stones which increase through growth, as crystals, possess a force not dissimilar to that of plants, whereby they are formed. The six-sided form of quartz he believed inexplicable or to be referred to such causes as give peculiar shaped leaves and flowers to plants.

Paracelsus preceded Peter von Arles in the vagaries of imagination which connected the metals and minerals with the seven planets and neighboring stars. These metals and minerals ejected from these distant orbs had fallen on the earth, but the quartzes, beryls and citrine had been "coagulated" in the "snow stars."

These oddities and mystifying fancies were reflected in the writings of Baptista van Helmont, which involved fabulous and metaphysical explanations, the crude substitute for more radical knowledge, which was then unattainable.

He, however, contested Paracelsus' assertion, the time-honored fancy of the Greeks, that quartz was an obdurate, irreducible ice, saying it was opposed to the essence of life that one thing should pass into another by an exterior influence, viz., that snow by cold should become crystal.

Since he further avers everything has its seed, beginning (Archeus), from which it ever new arises, and by which it receives its form, that, on account of special seed or germs (*propter speci-*

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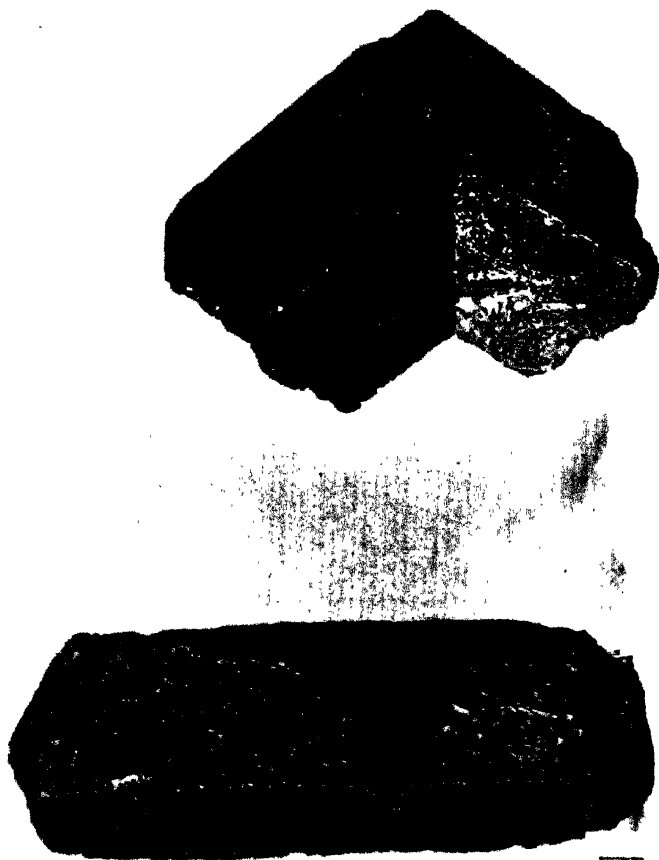
alia semina), stones received their configuration, not less constantly and regularly than the breeds of animals.

Crystallography received a veritable contribution in the mathematical dissertations of Johannes Kepler, who took five geometrical solids and evolved from them a series of forms, related and interdependent, of which many are exactly reproduced in nature.

The Jesuit philosopher, Athanasius Kircher, attacked anew the ever-present problem of crystalline forms, and, like so many of his predecessors, fixed his eyes on the enigmatical six-sided, pyramid-terminated quartz. He asserted that it derived its form from the peculiar endowments of the salt composing it, that in all salts a force moved their particles outward from a center along four, five or more lines, and so four, five or six-sided figures were created, the interlinear spaces being filled up by inrushing particles brought thither by a certain magnetic impulse.

Erasmus Bartholin, a distinguished mathematician, encountered the then newly discovered transparent (1670) Iceland spar.

He measured its angles, found out their permanency, even in the smallest cleavage fragments, dissolved it in acids, examined its colors, and with astonishment recorded its power of producing duplicate images (double refraction).

Huygens examined with the greatest care this phenomenon of double refraction, and so exhaustively followed up its laws as to leave little for subsequent investigation. He also detected double refraction in quartz.

He anticipated some modern molecular theories, in his suggestion that calc-spar (calcite) was made up of ultimate ellipsoids, heaped up in such a way as to form rhombohedral pyramids, and that the points of their consecutive contact along certain planes, parallel to the rhombohedral faces, formed surfaces of easy cleavage.

The microscope, which had been invented by Zacharias Jansens about 1590, had been improved, and began to play an important role in the advances made by natural science in every direction. Leeuwenhoek adapted it in an original way to mineralogical research, and revealed the minute crystallization of minerals, and turned his attention to the forms of alum, carbonate of soda, saltpeter, sulphate of copper, Glauber's salt, and sal ammoniac.

Isaac Newton calculated the thickness of the thinnest plates of mica and gypsum, the cleavage of which latter had awakened in Leeuwenhoek the liveliest admiration. It was indeed from his experiments upon the double refraction of light in calc spar that led Newton to advance his theory of the four-sided nature of light and to oppose the theory of wave-motion.

Physics were making strides in the domain of mineralogy, dawning conceptions of crystalline regularity were making a way for the generalizations of Steno, Romé de Lisle and Hauy, philosophical theories were realizing more fully the molecular forces playing in the substance of inorganic compounds; but chemistry had yet done little toward determining their constitution, and systematic mineralogy made unimportant progress, nor was to, until the elements of chemical analysis, perfected a century later, were elaborated.

Robert Boyle concludes this period of mineralogical development, following the division arranged by Dr. C. M. Marx in his work on the "History of Crystallography," which we have here in some parts almost literally presented ("Geschichte des Crystallkunde," von Dr. C. M. Marx, Carlsruhe und Baden, 1825).

Robert Boyle observed the geometric outlines of minerals, and made some observations upon the cavities in stones, lined with minute crystals formed, as he remarks, by a lapidifying juice (*succus lapidesceus*) of great purity. He also called attention to the lamellar texture of many minerals and made a long, patient series of notes and descriptions upon crystalline forms. The next stage of growth was now about to usher in the profound and varied facts which built up crystallography, and laid in chemical composition the foundation of a rational system.

The name of Steno is associated with the promulgation of a principle in crystallography which laid the foundation of the science upon a fixed law and brought into scientific unity a wide series of apparently discrepant mineral aspects.

Steno determined the angular invariability of natural crystals, viz., that, however distorted or modified, the faces of crystals made with each other the same angle under all abnormal or disturbing relations.

Bartholin, Jamitzer, Huygens, Boyle, had contributed important observations both on crystalline measurements and their physical constants; Huygens had speculated in a very modern fashion on the ultimate molecular constitution of minerals and Boyle hastened the determination of the specific gravity of minerals; Jamitzer and Bartholin had both made crystals and measured them, but Steno threw a new light on the subject when he affirmed that under all conditions crystals maintained a fixed crystalline unity. It was an affirmation which brought order out of confusion and sensibly led the way to the later determinations of crystallographic constancy which created a new science, of which Romé de l'Isle, Hauy, Bergmann, and Werner were the pioneers.

Steno was born in 1638, at Copenhagen, and died in 1687, at Schwerin. His life was devoted to study, and he ventured upon theological disputes with the same ardor with which he attacked mineralogical problems.

He insisted upon the growth of crystals from the outside by the addition of material derived from a fluid in which they might be immersed, not from some vegetative power of increase; he observed the unequal enlargement of crystals, their obliquity, and in the case of quartz explained the striated prismatic faces as due to the oscillation of the terminal (pyramidal) faces with the side (prismatic) faces.

He made out the fixed angular relations of the faces of the crystals, and in his speculations upon the cause of mineral increase, assigned the latter to the effect of magnetic attraction.

Steno was followed by his contemporary Gulielmini, an Italian, who corroborated the fixity of the crystalline angles, noted the restriction of one kind of crystallization to different species, as cubes to salt, octahedrons to alum, emphasized the fact that a crystal is made up, no matter how large, of innumerable similar smaller crystals, that these, fitting together, leave openings which give porosity to the crystal or contain water which may be expelled by heat.

His observations went a great way to extricate the subjects from the opprobrium of mere speculation, and mineralogy, on its physical side, at least, was beginning to assume, more and more, the outlines of a great science.

Keener students were constantly publishing their conclusions, descriptive mineralogy grew when Schenebeger described in great detail the variations of quartz, when Cappeller enumerated the structural types of mineral occurrences as spherical, conical, wedge-shaped, fibrous, micaceous, lenticular; when Bourguet definitely cast aside the idle, childish notions as to the origin of minerals from seeds and germs, and separated fossils proper from minerals; stalactites were no longer regarded as vegetable growths and the various efflorescences of salts were put into the category of mineral products.

Light was breaking over the subject of mineralogy in every direction, and the opening of the seventeenth century found a vast number of observations and inferences and some principles recorded.

The crystalline systems were not yet suspected, the range of material studied was narrow, being the artificial salts and precious stones, quartz and garnet, calcite, gypsum, and the more obvious metallic minerals, and mineral chemistry was struggling in im-

perfect ways to bring about a classification in minerals, an attempt which was necessarily hopeless until, at the end of the eighteenth century, the methods of analysis were created by Berzelius.

There was, indeed, chemical mineralogy, and Boyle, Becher, Stahl—the distinguished author of the Phlogiston theory—Henkel and Pott, had contributed to bringing processes of chemical analysis into use for determining minerals.

The remnants of a mythical age, however, still clung to the science. The sun was regarded as typical of gold, carbuncles, chrysolite, hyacinth; the moon, of alum, marcasite, white and green minerals; to Saturn were referred lead, copper, arsenic, sapphire, magnetite; to Mars the red and sulphurous species; and to Venus, beryl, lapis-lazuli, emerald, and silver. A rude and purely superstitious use of minerals, powdered and introduced into water, was practiced for medical purposes.

The discerning Henkel wrote about the metals as if they possessed animate affections, and assigned to them a certain moral order, while their peculiar affinities and unions yet affected the students with those impressions, derived from the alchemists, of love and friendship.

All this was inevitable; science was passing from the subjective to the objective stage. The custom of interpreting the motions of matter by the affections of the mind yet retained its hold in language and conceptions. All was vague, and, as it has been said, many scientific writers of the time were happy in being ignorant of their own ignorance.

Henkel and Pott, in the period lapsing from the seventeenth to the eighteenth century, were perhaps most active, and their chemical researches helped sensibly to introduce more exact definitions of mineral species.

Heat at various intensities was a common agent for chemical investigation. In this way the combined water of gypsum was detected; Boyle had subjected gems to the ordeal of the furnace, and averred that from most of the transparent minerals he had obtained a pungent vapor.

Henkel divided stones or minerals into four classes, according to their behavior when exposed to heat:

1. As they withstood fire.
2. As they were hardened by fire.
3. As they underwent pulverization upon rubbing after heating.
4. As they melted in fire.

TOPAZ (in Albite)
Tamagami Yama, Japan
Bement Collection, American Museum of Natural History
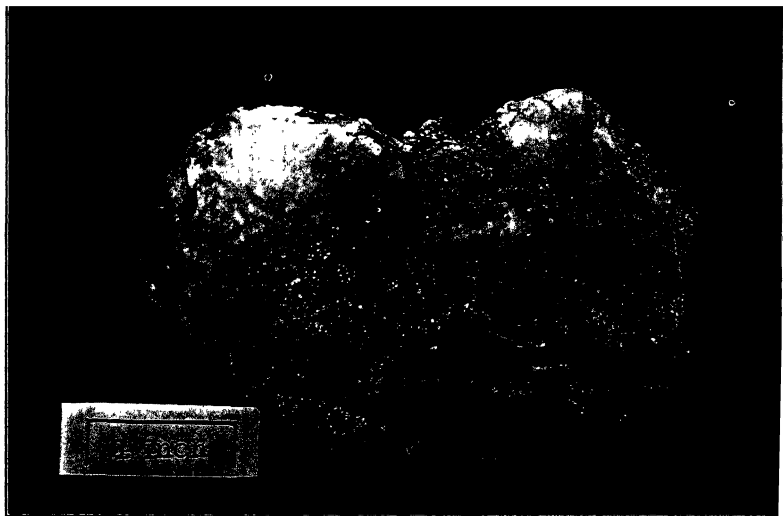
PHENACITE
Takowaja, Ural Mts.
Bement Collection, American Museum of Natural History

In the first class he arranged the diamond, ruby, beryl, sapphire, topaz, chrysolite, and silica; in the second, clay, serpentine, fuller's earth, and other clays; in the third, limestone, alabaster, sinter; in the fourth, sulphur, garnet, Oriental hyacinth, malachite, and Icelandic agate, viz., obsidian.

The fundamental constituents of stones were argillaceous substances, calcareous or metallic, and subsidiary to these, the salty, oleaginous, metallic, and saline-sulphurous. These distinctions were far removed from that definiteness of chemical composition which characterizes mineralogy, but still they contained a rude approximation of a general scheme not altogether irrelevant to the facts of nature.

In the realm of metals the species were perhaps more numerously separated, and the more common sulphides were recognized. But no means then existed for invading the unexplored regions of mineral production and bringing to view new species, assigning them their categorical position and giving them individuality.

Pott followed Henkel, and along the same lines of chemical investigation strove to delimit the relations of minerals. He divided minerals into four classes.

1. The alkaline and calcareous.
2. The gypsiferous.
3. The argillaceous.
4. The vitrescible.

In the first he placed the limestones, carbonates and calcite; in the second, gypsum; in the third, the clays and allied earths, which hardened in fire; and in the fourth, those silicates which fused in fire either alone or upon the addition of some flux, and in which were embraced the silicates, fluorides and many gems.

Pott separated alabaster from limestone, a confusion that had long existed; he noted the phosphorescence of minerals, struggled with the definition of talc, serpentine and the clays, and studied reactions.

Terms which have a specific, irreplaceable application were then applied most equivocally. The term marcasite was used in connection with rock crystals by miners; by alchemists it was applied to "undeveloped" metals.

Marcasita ferri was silica; marcasita cupris, a yellow or greenish-yellow copper ore (chalcopyrite); marcasita aurea was a zinc, tinged yellow with copper; marcasita argentea was bismuth. The alkaline earths were not yet separated, the silicates unknown, zirconium and beryllium undiscovered, and the metals but partially individualized.

Schemes of nomenclature, systems, were proposed by various authors. But as compared with those which have to-day reached so perfect a state, at least of specific definition, they seem very crude. The fundamental conceptions of chemical union were yet undeveloped, the list of elements approximate, and the methods of chemical analysis, as now understood unknown. So that on all the grounds of observation attainable, the expectation of making a permanent system was hopeless.

A number of students at the end of the eighteenth century began a revolution in mineralogy, aided by those advances in chemistry by which the constitution of compounds was elucidated. Among these Bergmann, Scheele, Kloproth, Bruckmann, Mayer, Gerhardt, Hoffman, and many others became distinguished.

The science of chemistry was advancing toward a determinate condition. Priestley, Lavoisier, Scheele, Cavendish, Richter, Dalton, were introducing a knowledge of the nature of combustion the theory of atomic unions, a clearer thought in chemical philosophy, and above all an appeal to the balance as the judge of chemical conclusions.

Somewhat before this time the divine Linnaeus had inaugurated the momentous change in zoological and botanical nomenclature which has placed him in the highest rank of scientific benefactors. But Linnaeus also essayed the difficult task of putting in order the confused retinue of mineralogical facts, although as he said in his preface, he had deputed to others this subject, and, unless importuned (lacessitus), did he consider them.

This system of Linnaeus has a double interest as standing somewhere between two periods in the history of the development of mineralogy, the period of the mediævalists and the moderns, as holding yet some of those semi-metaphysical notions which made up the mineralogy of speculation and as incorporating some of the facts and observations which laid down the foundations of the experimental science.

Linneaus alludes with admiration to the labors of Woltersdorf, Wallerius, Cronstedt, Vogel, Just, Swab, "who, inspired, with the divine breath, have given their observations to the learned world, to whom, since with infinite labor and exhaustion (sudore) they have penetrated the abyss of nature, and the depths of mountains, glory forever is due from all just judges."

To the eye of Linnaeus the mineralogical world seemed a generative womb wherein through the conjunction of male and female elements the propagation of mineral species went on in a sort of inorganic accompaniment to the wide fecundity of organic nature.

From the water, the omnipresent ocean, arose in the beginning everything, and this humid, cold, passive, conceiving water, fecundated by the dry, heating, active, generating air, brought forth two mineral principles, the masculine, sharp, clear, crystalline salts, and the feminine, fixed, viscid, opaque, cohesive earths.

These salts, sapid, polyhedral, diaphanous, complex, decomposable (solubilia) into infinitely minute particles, nevertheless always alike, uniting together again and again into similar larger particles, generate by crystallizing in and from various earths, various stones.

These salts were nitrum, muria, natrum, alumen, and Linnaeus calls them the fathers (patres) of stones. Nitrum, atmospheric or gaseous in nature, was the mate of sand (arenam), silica, etc.; muria, marine in nature, the mate of clay (argilla), all argillaceous matter; natrum, animal in origin, united with lime (calcem), and alumen, vegetable in disposition, penetrated the ground (humus).

These four earths, argilla, arena, humus, and calx, were the mothers (matres) of stones.

Linnaeus added to this list of saline crystallizing elements borax, vitriolum, mirabile, amarum, all alkaline salts—vitriolum, a type of sulphates, including many metallic salts—whose obvious crystallization was so prevalent and whose crystallizing efficacy he invoked as in some way expressive of all other forms of crystallization.

In his classification the earths (terrae) come first as a class, viz., those mineral matters in which argilla, arena, humus, and calx prevail. He divided them into the talcose, ponderous, calcareous, argillaceous, and siliceous. The talcose embraced talc, serpentine, asbestos, actinolite, and hornblende; the ponderous, barite and crossopetra; the calcareous, chalk, tophus, calcite, lamellar calcite (schistospathum), inolite, stalactite, pisalite, marble, foetid limestone (suillus), tremolite, stellatis, humus, marga, magnesite, gypsum, hepaticus, fluorite, apatite; the argillaceous, various clays with lava, mica, opal, zeolite, and schorl.

In the siliceous, Linnaeus put olivine, feldspar, petrosilex, jasper, emery, zircon, lydian stone, garnet, sand, quartz, chalcedony, corundum.

The salia ·or salts formed his second class, and these were natrum, carbonate of soda, borax, muria, common salt, nitrum, nitrate of potash, mirabile, sulphate of soda, amarum, Epsom salts, alumen, alum, vitriolum or alkaline sulphates.

To the crystalline form of these salts he wished to refer the crystalline forms of the minerals, and he regarded these salts as crystalline categories to which all crystals were to be referred.

There was not, however, in his mind any suspicion of the six systems, geometrically individualized, which Hauy and his followers defined.

The class of combustibles followed the salts, and among these were bitumen, amber, graphite, and sulphur. Class fourth comprising the metals as then known, being uranium, wolfram, magnesium, antimony, zinc, molybdenum, tin, cobalt, iron, arsenic, copper, nickel, bismuth, silver, lead, mercury, gold, platinum.

He enumerated the known crystals under hexahedral, octahedral, decahedral, dodecahedral, fourteen, eighteen, twenty-four, twenty-six, thirty-six sided solids with rhombic, rhomboidal, rectangular, trapezoidal, and scalene faces.

The names given by Linnaeus were often generic in character, and what are now considered as distinct minerals were grouped under one designation. Thus under gemma we find ruby, sapphire, topaz, hyacinth, spinel, aquamarine, beryl, chrysoberyl, emerald, garnet, while again under quartzum a long list of varieties is given, all referable to quartz, but characterized by such peculiarities as to-day distinguish the examples of this omnipresent mineral, as fibrous, pitted, eroded, cellular, lamellar, globular, cylindrical (?), granular, green, unctuous, tabular, rock crystal, etc.

The book of Linnaeus upon minerals in the kingdom of nature was a systematic work, it marked the progress made in reducing the numerous observations of students to some sort of order, and gathered in a scientific fashion all of those observations and started out a practical check list.

But the mineral kingdom was very poorly understood as yet, and the modern collector would wander hopelessly amid the pages of Linnaeus to recognize many of the more common occupants of the shelves of his cabinet. Linnaeus indeed was but partially acquainted with the chemical researches of his day, and his work is scarcely an adequate reflection of the researches of contemporaries.

Woltersdorf, in the preface to his mineral system, wrote about this time: "The first and best distinctions to be followed in a classification of minerals must be based upon their constitution. As minerals neither live, nor grow, nor feel, they are not organic in nature, have no anatomy and sense apparatus, by which they can be distinguished. Therefore in this matter we should place no reliance on the exterior appearance. There are mineral species of one genus which in no way resemble each other. On the other hand there are found some of entirely separated classes which have the same form. We must therefore determine the relationship and the differences of minerals, according to their composition, or by

TOPAZ
San Luis Potosi, Mexico

BLUE TOPAZ
Mursinka, Ural Mts.

Bement Collection   American Museum of Natural History

the material of which they are made, and from these classes, orders and genera are fixed."

Names were in great confusion, and no authority established a name when introduced, nor rejected it, so that each author had free play, and that liberty, in conjunction with misunderstanding of the nomenclatures previously used, added to the perplexity.

Garnets were known as carbuncles, anthrax, pyrope, amethyst-izonton, sistites, carchedonius, sandaresos, lychnites, jonis; chrysolite as leucochrysos and mellichrysos; emerald as cholos, chalcosmaragdus, pseudosmaragdus, galactite, and so on. A desire for making systems was prevalent, and numerous writers ventilated their plans at a time when no rule or criterion was established to make any permanent.

The latter years of the eighteenth century brought in new researches, and mineralogical physics and chemistry began to coordinate in lines of true affinity the minerals that were known and to add to their list minerals that were either new or had been disengaged from some previous synonomy.

Prof. Pattison Muir has pointed out with great care the growth of a true chemical conception of "salt" as a chemical fact. It was recognized at quite an early period in the eighteenth century that the salts were combinations of an acid and a so-called alkaline or earthy principle, but the subject was clouded over by ignorance as to the real facts of the case.

Then came the advanced views upon combustion introduced by Lavoisier, with the kindred facts of oxidation throughout the range of metallic bases. The acids were regarded as oxygen compounds and the bases as oxygen compounds, which in combination produced salts which were also oxygen compounds.

Davy furnished the brilliant generalization that the acid element of a salt was electro-negative and the alkaline, earthy or metallic, electro-positive, while his decomposition of the alkalies and the earths and the production of their metallic bases threw into a common category all of them.

His theory led to the thought that the salts were the unions of oppositely electrified bodies, which thus secured between them electrical equilibrium. Then followed the discovery of chlorine, the composition of hydrochloric acid and the gradual withdrawal of the assertion that all salts were oxygen compounds, since muriatic acid formed salts and it contained no oxygen, and it formed them directly with the unoxidized metals.

Berzelius continued these speculations and constructed the great system of dualism in chemistry. He regarded all atoms of sub-

stances as possessing both kinds of electricity accumulated at their polar extremities, but that one or the other, positive or negative, preponderated, and that the affinity of the atom was determined by that preponderance. If the atom was negative in excess, it attracted an atom in which positive electricity prevailed, and so on.

He then continued building up compounds from these primary combinations; compounds of the first order were made up of the combination of atoms of two or more (organic) elementary atoms; compounds of the second order were made up by combination of elementary atoms with the compounds of the first order, or by the combination of two or more compounds of the second order.

These views overthrew the Lavoisierian conception of oxygen as the acidifying element, and they led Berzelius in the course of his experimentation to detect the acidic character of silica. Silica, thus revealed as playing an acid role, introduced a whole new range of ideas in reference to mineral compounds and the widely distributed silicates were for the first time given a truly systematic position.

Cronstedt had, years before, attacked the determination of minerals and had devised a system of blowpipe examination which was most fruitful in revealing the more evident features of the minerals as they were found in the field.

His little laboratory comprised the blowpipe, a candle, a pincers, three flasks with a few reagents, as borax, carbonate of soda and microcosmic salt; a hammer, a steel plate, a magnet, a file, a magnifier, completed his equipment, with charcoal as a surface for holding the specimens tested.

It is surprising to learn in this early treatise on blowpiping by Cronstedt, how far this sort of mineralogical research had advanced and how careful and accurate are the directions given by its author for the detection of combinations and peculiarities of reaction.

The zeolites were first in their peculiar chemical behavior separated by Cronstedt, who pointed out that they dissolved in nitric acid and that the solution possesses the peculiar property, after some time, of assuming the consistency of a jelly, which will not fall out of the vessel containing it, when the former is inverted, referring to the familiar gelatinization of these hydrous silicates when decomposed by acids.

Lehman, a German mineralogist and chemist, had also applied his studies to the separation of metals and their compounds, and to their various natural occurrences. He believed that in all bodies there were three separate principles—the vitreous, which formed the greater and more solid portions, the combustible, upon which

depended malleability and fusibility, and the vaporous-mercurial, which imparted metallic luster and weight.

Marggraf, Scopoli, Bergmann and others developed the chemical side of mineralogy, though for the most part their investigations were with the metals and metallic compounds, and the more common earths—the clays, sands, quartzose rocks, limestones, and iron oxides; while the precious stones began to play a part in the experiments of the chemists.

Klaproth, whose work extended into the nineteenth century, added a new and brilliant list of investigations by the results of which the oxides or earths of uranium, zirconium, strontium, titanium and cerium were placed in the catalogues of mineral bases.

In 1774 the great Werner, the Professor of Mineralogy and Mining at Freiberg, published his celebrated essay on the "External Characters of Minerals," in which he undertook to define in detail those features of minerals, other than chemical and physical, which appertain to color and form. Werner separated the colors of minerals in a long list of varying shades which seem somewhat superfluous and are seldom constant in one species; thus white was distinguished under the following variations:

Snow-white.—Quartz, flos-ferri, cerussite.
Reddish-white.—Kaolin, steatite.
Yellow-white.—Zeolites, white amber.
Silver-white.—Native silver, bismuth, arsenopyrite.
Greenish-white.—Talc, amianthus.
Milk-white.—Opal.
Tin-white.

In green he recognized wood-green, mountain-green, grass-green, apple-green, leek-green, siskin-green; in yellow, sulphur-yellow, citron-yellow, gold-yellow, straw-yellow, wine-yellow, Isabella-yellow, ocher-yellow, orange, and so on with similar elaborations in gray, black, blue, red, and brown.

His efforts at the separation of crystals were not permanently valuable; he mentions six fundamental forms, the twenty angled, the eight angled, the prism, the pyramid, the table, and the wedge. Cleavage, transparency, solubility, and hardness were determined by him for many minerals, and upon this kind of analysis he reformed the current systems, and attempted the establishment of a fixed nomenclature.

His fame spread through Europe, students flocked to his instructions, and a new group of mineralogists issued from the doors of the Freiberg Institute that were in their turn destined to advance

the science. Among these were Andrada, Jameson, Breithaupt, Brochant, Karsten, Weiss, and others, all of whose labors have been commemorated in the science in mineral species bearing their names.

While advances were thus constantly claiming the attention of the chemical mineralogist, the physicists were pushing the crystallography of minerals to the final stage of its development. The work of Steno was continued by Romé de l'Isle and Hauy, and when the latter at the beginning of this century published his first edition of the "Traité Mineralogie," the science of crystallography was practically accomplished. Certainly much was added and the optical properties of minerals were to receive large additions, but the theory of the synoptical systems had obtained from Hauy a full and patient exposition.

Romé de l'Isle measured an extraordinary number of crystals, and determined the invariability of the crystalline angles, the derivation of secondary forms from primitive ones, and assumed the reference of crystals to six leading forms: the tetahedron, the cube, the octahedron, rhombic prism, rhombic octahedron, and hexagnal pyramid.

He proved the symmetry of crystalline faces, the twinning of crystals, and illustrated it in gypsum, zircon, staurolite, feldspar, spinel, marcasite and cassiterite. He understood the nature of pseudomorphs and relied upon chemical analysis for those distinctions in composition which separated mineral species of the same crystalline habit.

In the closing years of the eighteenth and the opening years of the nineteenth century, the development of mineralogy was rapid and various, and in no feature more remarkable than in crystallography.

Hauy pushed this fundamental principle in mineralogy the farthest and put crystallography in possession of those conceptions which were needed to open the way to a philosophic treatment. For instance, in the isometric system he described the process of decrescence, by which a cube declines through the truncation of its angles into an octahedron, while its faces produced in diminishing pyramids produce the rhombic dodecahedron. This led to the mathematical calculation of possible faces and gave to the crystallographer the power of prophecy, and in the calculation of angles the means of verification.

Hauy devised a system of symbols, no longer used, determined the rational relation of the axes of different pyramids and prisms, beginning with some base form, pointed out that hemitropes or revolved forms were revolved upon a geometric plane, and the law

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Delaware Co., Pa.
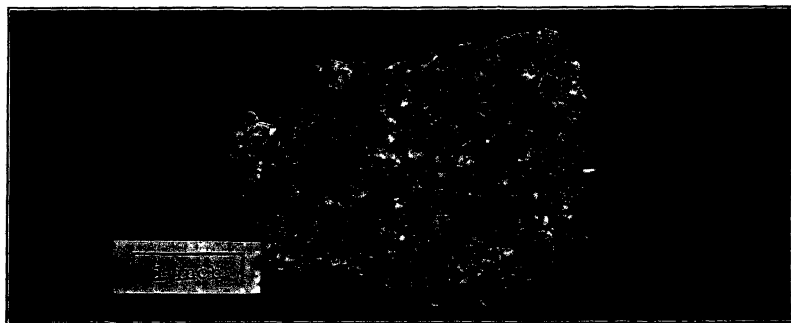
DANBURITE
Russel, N. Y.
Bement Collection, American Museum of Natural History

of symmetry, by which a modification of one part of a crystal imposes a similar modification upon similar parts. Hauy successfully applied his crystallography to the determination of species, and his correction of previous errors of identification was sustained by chemical analysis.

The zircons of Norway, regarded as vesuvianite, were determined by Hauy; he showed the specific character of euclase, separated meionite from hyacinth (zircon), separated the minerals compounded under the name of schorl, united the various forms of specular iron, and divided the isometric (pyrite) from the orthorhombic (marcasite) form of iron sulphide.

Hauy's views and system were not received without opposition, even by well experienced crystallographers, but his new and exact results stimulated students, and there were published several systems of crystals differing from his.

Weiss, who undertook the translation of Hauy's mineralogy into German, devoted his life to crystallography, and he emphasized the nature of crystalline axes or directions along which with varying intensities the crystalline forces act. It was Weiss who developed the crystalline categories of hemihedrism.

Hauy had formulated a system of determinants for crystals based upon the relations of various dimensions other than the axes, as in rhombohedral forms the relations of the diagonals of the faces, in hexagonal forms the relation of a normal from the center of the base to one side, to the height, in tetragonal forms relation of a side of the base to the height of the prism, in pyramids the relation of one-half of a side of the base to half the height, in orthorhombic crystals the relation of half of the side of the base to half the height.

Weiss expressed the position of a crystalline face by its reference to the three axes of the crystal. The axes became its coordinates and the face was determined by the points of intersection made by it with them. This system was simple, comprehensive and natural. It enters into the nature of all succeeding systems, and assisted methods of mathematical calculation.

Naumann, one of the most distinguished of the disciples of the Weiss school, fixed upon the normals produced from the center of a crystal to the faces as affording means for the delineation of the crystal. These normals projected intersected the surfaces of an imaginary sphere, embracing the crystal, and the horizontal projection of these points of intersection prepared the geometrical solution of the crystal.

Weiss had called the attention of crystallographers to the importance of zones, viz: Groups of planes between which the edges

or mutual intersections are parallel, but it was Naumann, to quote Prof. Fletcher, who "proved that the fact that all possible crystal faces can be derived by means of the intersection of zones is a necessary consequence of the rationality of the indices; that, indeed, the law of zones is mathematically identical with the law of rationality."

The succession of distinguished thinkers in crystallography was now very striking. Hausmann, Mohs, Haidinger, Miller, Bernhardi, Quenstedt, Breithaupt and others, investigated the nature of crystalline structure in its geometrical relations and endeavored to reduce severally adopted plans of notation by which crystals could be described.

Among these celebrated men, many of them gifted with extreme mathematical insight, Mohs may be regarded as the greatest. He established the six systems which crystals assume, he proved the existence of the inclined systems, an honor shared with him by Weiss, and he described the mutations of crystalline combinations more fully than had been done before.

Mohs endeavored to bring into harmonious arrangement the system of mineral species, with the systems of botanical and zoological species, and to establish generic and specific names based on the Linnæan invention of binomalism. It was a fruitless and misleading effort, and only introduced an alien system which confused and delayed the progress of the science.

While crystallography was thus making rapid strides in advance, and it demanded the highest intellectual strength to follow the speculations of its professors, mineral physics was accompanying it in a sympathy of development that expressed the close relationship of one with the other.

When the six crystalline systems had been established on geometrical grounds, it was felt that their virtual existence required a stronger corroboration from physical properties, especially optics. The limits of the uniaxial and biaxial crystals was a wider boundary than the system indicated, and it was desirable that in the biaxial systems—the orthorhombic, monoclinic and triclinic—differences of optical reaction should be discovered marking off one from the other.

Naumann and Herschel established the validity of the systems. It was found that in orthorhombic crystals the two lines bisecting the angle of the optic axes internally and externally, and a third line perpendicular to both, are constant in direction in the crystal, whatever the color of the light; in the monoclinic only one of these lines is constant as the color varies; in the triclinic none of the three lines has any constancy of direction (Fletcher). Brewster,

Haidinger, Biot, Malus, Senarmont, Herschel, and others, were investigating the double refraction of crystals, the polarization of light, its circular distortion, pleochroism, by which in the line of different axes the light was differently colored, the anomalous behavior of crystals which contradicted the usual law of their system.

For instance, chabazite afforded both positive and negative double refraction, penninite gave very different angles between the optical axes in different specimens, twinning crystals which should be biaxial appeared uniaxial, crystals without normally double refraction possessed it.

These peculiarities and contradictions afforded the physicists numerous problems whose solutions were followed by a wonderful series of further optical discoveries. It was shown that the lamellar overgrowth of crusts of new material produced polarization by reflection from the interlamellar surfaces, that heat and pressure influenced the optical properties, that the angle of the optical axes in biaxial crystals changed with the color of the light.

Then came the discovery of elliptical polarization, conical refraction, asterism, and the peculiar Brewster figures which Babinet showed was the result of diffraction. The electrical properties, elasticity, gravity, density, phosphorescence, and other physical properties were being, at this stage in the history of mineralogy, closely studied.

The relations of the axes in the various systems were found reflected in the physical reactions of minerals in different axial directions. Thus in expansibility the crystals of the isometric system expand in all directions equally, in the hexagonal the expansion in the direction of the principal axis is different from that in the lateral axes, in the orthorhombic the expansion is variable along all three axes.

The hardness of minerals was also found a property unequally developed upon different faces of a crystal, and the differing electrical properties of the opposite ends of the hemimorphic tourmaline had been detected by Hauy, while Brewster showed the pyroelectricity developed upon heating a long list of minerals.

Phosphorescence and fluorescence were investigated in minerals. Brewster demonstrated that some fluorites were phosphorescent in parts or veins, while Pearsall showed that many minerals which failed to display phosphorescence through ordinary heating became phosphorescent through an electrical shock.

Isomorphism and polymorphism were now extensively investigated, and the singular fact that the temperature of the crystallization influenced the crystalline form was soon announced, results

prophetic of the singular properties of boracite made known by the studies and experiments of Ernest Mallard. It was proved from his observations that above 265 degrees boracite is isometric and below that temperature orthorhombic. In this latter instance and of very recent discussion, the orthorhombic elements are assumed to be almost cubic in their proportions, so that a slight re-adjustment of the molecules leads to an inversion of one form to the other.

Amorphism and pseudomorphism were also ingeniously studied and speculations framed to meet their various problems, while a peculiar condition, named by Scheerer as paramorphism, was described, wherein a mineral having one general exterior form incloses constituents having a different crystalline character. He instanced a natrolite of Norway which was orthorhombic, but assumed a monoclinic habit.

The occurrence of minerals were industriously examined, and in the middle of this century a host of observers were steadily acquiring facts as to the interchanges, relations and physical features of minerals, which gave the science an almost new aspect. Among these were Fuchs, Haidinger, Scheerer, Delesse, Bischof, Breithaupt, Dana, Kenngott, Sorby, Von Rath and many others. Daubree, Senarmont, Rose and others scarcely less distinguished were now reproducing minerals and invoking every kind of chemical reaction to build up in the laboratory the minerals of which the chemists had already furnished the composition. In short, the modern epoch of scientific thought revealed in mineralogy a most diversified field of experiment and observation. But chemistry more and more inclosed the domain of mineralogy, and in the extension of analyses, the discovery of more exact methods of analysis, new species, were being constantly added, while at last a norm of reference became established as to the relationship of minerals, and so the modern chemical classifications slowly emerged.

The modern movement in the widening and deepening studies in mineralogy has gone on unceasingly, and now in its crystallographic relations the treatises on symmetry have attacked the problems of molecular form and position, and in its chemical aspects began those speculations upon the evolution of mineralogical types in which Tschermak and Clarke have offered distinguished assistance.

Whereas in 1832 few minerals were in composition free from all dispute, now chemical formulæ are exactly determined, and the great groups of the amphiboles, pyroxenes, scapolites, garnets, micas, feldspars, have been defined. The tendency has been to
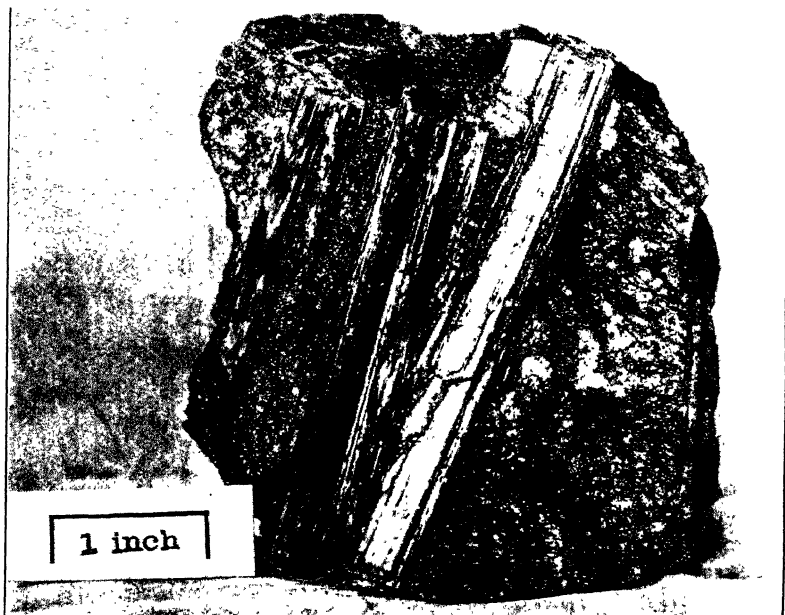
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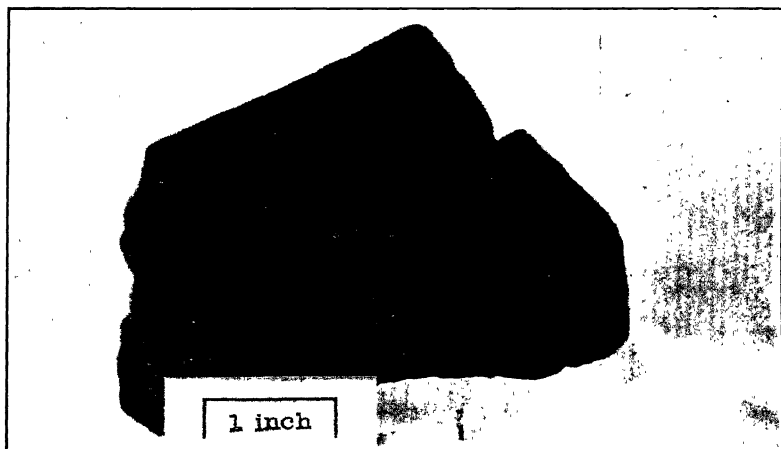
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Delaware Co., Pa.
Bement Collection, American Museum of Natural History

make mineralogy a chemical science, and it seems to grow constantly clearer that in chemical composition is to be found most of the determinative characteristics of mineral species. The dependence of physical or optical qualities upon composition has only recently been demonstrated in a paper by Prof. Penfield, who has shown that the varying inclination of the optic axes of topaz arises from the varying amounts of fluorine present.

It may finally be claimed that in a sense mineralogy approaches a finished science. Special investigations may extend the list of species, or reveal qualities in old ones not hitherto suspected, but its broad outlines are drawn and they are solidly filled in. The future development of mineralogy lies in the field of paragenesis—the associations and affinities of minerals—and in the synthetic production of them and their pyrogenetic history.

A closer review of some of the work done in mineralogical science since 1890 may now be permitted, though of necessity much of it is an enlargement, or a particularization, of lines of research begun long before that date.

C. Doelter in 1890 reproduced the zeolites (*apophyllite, okenite, chabazite, phacolite, heulandite, stilbite, laumontite, thomsonite, analcite, natrolite, scolecite, prehnite*); Max Bauer in 1891 studied the paramorphoses or pseudomorphoses of minerals with reference to that of *rutile* after *brookite* from Magnet Cove, Ark. and of *rutile* after *anatase*. Doelter in 1894 investigated the chemical relations of some dimorphous minerals (*andalusite* and *cyanite, orthoclase* and *microcline, epidote* and *zoisite, enstatite* and *authophyllite, diopside* and *actinolite, pyrite* and *marcasite, zincblende* and *wurtzite.*)

Bruno Doss in 1894 artificially prepared Anatase and Rutile, by saturation of a bead of microcosmic salt with titanium oxide. Muthmann and Kuntze, R. Brauns, Ben Saude, contributed observations upon the optical anomalies of metric crystals, in which emerged the idea that in the process of crystallization, *for an instant,* upon hardening not only a contraction of the mass, as in colloidal bodies, occurs, but the form of the crystal has an influence upon this contraction which gives rise to various and contrasted effects, according to the nature of the surrounding mass, according to pressure, to temperature, and the concentration of the solution and always similar effects under similar conditions.

The synthetic studies of Doelter were always a subject of perennial interest to that industrious investigator, and they were continued with interesting results. He found upon melting potash-mica, that recrystallization yielded leucite and nephelite, lithia-mica also produced leucite and nephelite; zinnwaldite, leucite; magnesia-

mica, augite, spinel, chrysolite, meionite, orthoclase(?); clinochlore, spinel, olivine, augite; tourmaline, olivine, spinel; axinite, augite; datolite, olivine, anorthite, pyroxene(?); epidote, augite and anorthite, and, with mixtures of fluoride of sodium and calcium, anorthite and meionite. Zoisite and manganese chloride yielded manganese garnet; garnet itself with a fluoride, biotite, or with less fluoride, anorthite, meionite, augite.

Doelter further experimented upon the syntheses of hornblende, wernerite, acmite, and came to the conclusion that through the influence of fluorides, chlorides, and through the influence of varying temperatures a fixed mixture gave most diverse results. O. Mügge continued a long series of mineral observations. Reinhard Brauns extended the studies of E. Mallard and Retgers upon polymorphic haloid compounds. F. Rinne examined the interesting character of waters of crystallization in Heulandite.

Then the crystallographers elaborated the further application of Symmetry under the name of *Syngonie* hinting at the abandonment of systems, as delimited, and insisting that geometrical systems of crystals are those groups of the classes of symmetry which are established on the bases of the relationship of the crystals to the *zone* laws.

Linck had defined the relations of the physical properties of crystals with their chemical composition as constituted (1) by the direct dependence of the crystallographic properties of a substance upon its molecular weight, most sharply emphasized when the elements and their combinations are arranged according to Mendeleef's periodic law, and analogous crystallized bodies are compared with each other; (2) by the fact that analogous crystallized elements of one grade in the Mendeleef system, were related to crystallized elements of another grade in this same system with regard to all their qualitative and quantitative properties or, to quote Prof. Miers: "for example, potassium, rubidium, and caesium are three monivalent elements occupying consecutive positions in the even series of Mendeleef's table, i. e., three elements giving rise to eutropic compounds, and they act as vicarious constituents in a number of isomorphous salts; as regards its atomic weight, rubidium lies between potassium and caesium. Tutton has compared the simple sulphates of these metals, K_2So_4, Rb_2So_4, and Cs_2So_4, and has shown that both as regards crystalline form, specific gravity, thermal expansion, and corresponding refractive indices, the rubidium salt lies between the potassium and caesium salts." This Linck called *Eutropie,* and that whereas Isomorphie demanded that by analogous chemical constitution similar geometrical and physical properties

of the crystals result, Eutropie showed that with the same radical united with changing elements of a relation line in the periodic system, there were similar crystal forms, and similar geometric, physical and chemical constants, *but* changing in equivalence to the changing atomic and molecular weights.

J. Martini's "Beitrage zur Kenntniss des Quarzes" was an illustration of the improved and deepened insight into crystallographic relations as pyro-electric methods were employed, and etching figures were interpreted in their relations to crystallographic structure. G. Tammam in 1903, in his paper, Crystallization and Fusion, summed up his work in the conclusion that the Plasticity of crystallized substances was the reciprocal interior movement and was an unique property of crystals. This increases with the deforming force, with increasing temperature, and attains at temperatures in the neighborhood of the melting point a very considerable importance. Substances not usually, at ordinary temperatures considered plastic become so as the melting point is approached, that the melting point by compression as well as by dilation is lowered, that the curves of equal plasticity of materials descends to lower temperatures with increasing pressure. This was again further studied by L. Milch.

If one will take up the *Beilage* volumes of the Neues Jahrbuch fur Mineralogie from 1890 onward the new aspects of mineralogical study, theory and demonstration will be impressively shown. Pockels, after Rontgen and Kundt, studied the change in the double refraction of Quartz in an electric field when the lines of force in the latter ran at right angles to the optical axis, and showed that the observed alterations qualitatively are explained on the hypothesis that they are caused by *deformation,* which quartz undergoes by reason of its piezoelectric properties: the same investigator wrote upon the estimation of the optical properties of isomorphous mixtures deduced from the same properties of the simple substances involved in the mixture, also upon the elastic deformation of piezoelectric crystals in the electric fields.

Trauhe studied the acetates and their crystallographic features, the pyro-electric properties of *prehnite,* the chemical composition and the crystallographic form of artificial zinc-oxide or *wurtzite,* and the crystal forms of Cubic and optically uniaxial substances whose solutions show optical rotation. Trauhe also investigated etching figures assuming that etch-figures were the most trustworthy guides to the crystal forms as, at least, related to the degree of symmetry to be assigned to the mineral. He examined Cuprite, Phosgenite, Wulfenite, Scheelite, Chalcocite, Cyanite, Tourmaline, Vesuvianite, Dioptase, Willemite, Nephelite, Beryl, Adularia.

Beijerinck in 1897 contributed an exhaustive paper upon the electric conductivity of minerals, claiming that electric conductivity is a "substantial property which in the case of opaque and heavy or massive minerals is of the greatest importance;" that "no physical property in itself, between wide limits, can be determined with greater accuracy than the electrical resistance of a substance, and that the changes of this resistance, through other physical influences, as for instance the temperature, is in the highest degree characteristic." His tables embraced 375 substances. He concluded that the electrical conductivity of minerals varied between extreme limits, that it was dependent upon the chemical constitution of the minerals, and upon their position in the System. Chemically isomerous as well as physically allotropic bodies are greatly contrasted in their electric conductivity whereas isomorphous salts are much less contrasted, and differ amongst themselves no more than different metals. Slight differences are evident in different crystallographic axes in anisotropic minerals as in rhombic Marcasite, in the direction of the three axes. Monoclinic and triclinic crystals are non-conductors, above low resistances, but there is no apparent direct relation between the class of symmetry and the galvanic conductivity.

The System of Minerals is therefore divided into two classes; to the *conductors* belong the Metals, Alloys, some Metalloids, the greater number of Sulphides, Tellurides, Selenides, Bismuthides, Arsenides, Antimonides, a part of the Oxides, and some Haloids; to the *insulators* belong the larger part of the Metalloids, some Sulphides, the greater part of the Oxides, almost all Haloids, and all sulpho- and oxygen salts. The electric conductivity in the greater number of hitherto investigated binary compounds, increases with increased temperature, a relation directly contravened by the metals; with these latter increasing temperatures diminish conductivity. Of the non-conductors the complicated combinations are apparently better conductors at higher temperatures. Among the binary compounds whose electro-negative elements are found in the 7th series of the Periodic System, the conductivity increases with the atomic weight. On the contrary the exact opposite obtains with electro-negative elements of the 6th series of the Periodic System. So the conductivity rises in the oxides, sulphides, selenides, tellurides, of one and the same metal, while with the fluorides, chlorides, bromides, and iodides the opposite occurs.

In 1899 G. Bodländer treated the now important question of "solid solutions," which Van't Hoff first promulgated. This is a profound study having to do with the intermixtures—solution so-
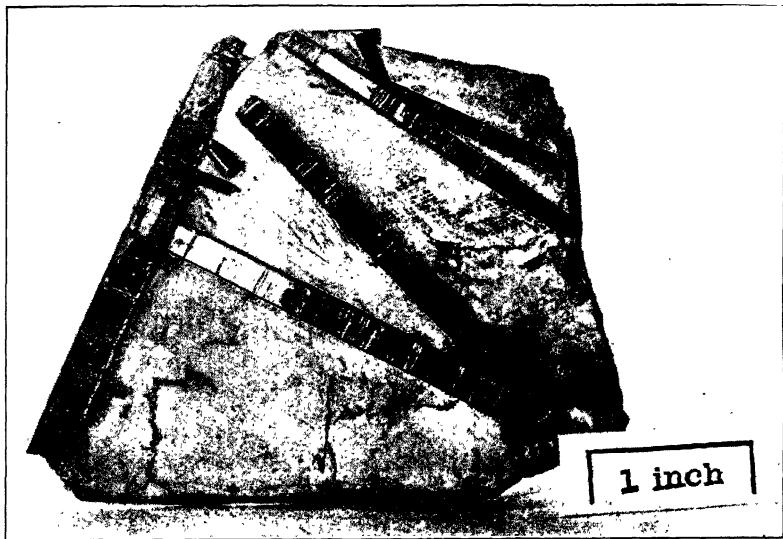
CYANITE
St. Gothard's, Switz.
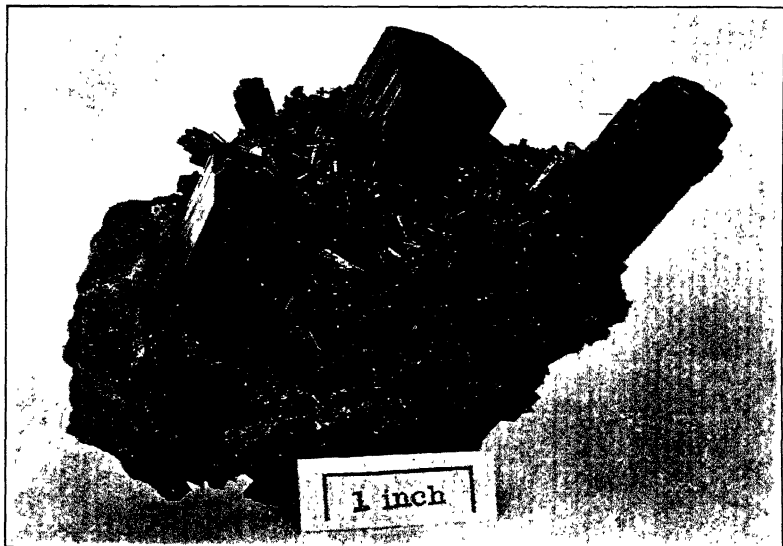
ILVAITE
Is. of Elba, Italy

called—of solids in each other.   The substances experimented with
were iodide and chloride of silver, the nitrates of potassium, thal-
lium, rubidium, caesium, lead, strontium, silver; napthaline and
B napthol; chlorate of potassium and thallium; dichlorbenzol and
dibrombenzol, as also trichlorphenol and tribromphenol, u. s. w.
F. Solger illustrated the value of the Brewster light figures from
etch cavities on crystal faces, for the determination of the crystal-
lographic character of the etchings.

E. Sommerfeldt undertook an investigation of the question as
to whether in the mixture of substances in a crystal body, whose
properties qualitatively were determined by such a mixture, there
was also a quantitative relation of the properties of the mixed crys-
tal to those of the involved constituents.   O. Mügge studied the
arrangement and structure of "mimetic" crystals, or of crystals,
which change, upon heating, their crystallographic reference.   Thus
Aragonite, heated, became calcspar, and, in this case, the conclu-
sion was that we can postulate with certainty that the change of
Aragonite to calcspar is connected with a variable change of the
geometric constants.   His examination included *strontianite, leucite,*
leadhillite, calcium-chloro aluminate.

O. Mügge in 1903 published a very important and instructive
paper upon the regular intergrowths of different minerals.   A
fairly exhaustive record of the topics in this splendid paper de-
serves a place in this historical review.   They were copper and
cuprite—pyrite and galenite—galenite and tetrahedrite—tetrahedrite
and pyrite—tetrahedrite and sphalerite—arsenic and arsenolite—
pyrrhotite and galenite—pyrrhotite with pyrite—magnetite with
hematite—miersite with iodyrite—pyromorphite and galenite—
cristobalite and tridymite—pyrargyrite and argentite—fluorite and
quartz—perovskite and ilmenite—cerargyrite and iodyrite—magne-
tite and rutile—boleite and cumengeite—galenite and chalcopyrite—
cobaltite and chalcopyrite—sphalerite and chalcopyrite—tetrahedrite
and chalcopyrite—argentite and chalcopyrite—scheelite and fluorite
—galenite and cotunnite—galenite and bournonite—pyrite and ar-
senopyrite—galenite and arsenopyrite—magnetite and hornblende—
magnetite and muscovite—magnetite and prochlorite—muscovite
and sylvite—calcite and quartz—calcite and hematite—calcite and
dolomite—calcite and nitre-dolomite and nitre-nephelite and can-
crinite—hematite and rutile—corundum and rutile—catapleiite and
zircon—proustite and marcasite—calcite and aragonite—pyrrhotite
and marcasite (and arsenopyrite)—calcite and barytocalcite—il-
menite and augite—dolomite and prochlorite—calcite and biotite—
tourmaline and muscovite—hematite (and ilmenite) and muscovite—

muscovite and nitre—quartz and orthoclase—zircon and xenotime—rutile and anatase—chalcopyrite and polybasite—rutile and brookite—chalcopyrite and bournonite—rutile and muscovite—mellilite and biotite—xenotime and monazite—torbernite and autunite—andalu site and sillimanite—witherite and barite—stephanite and polybasite—olivine and serpentine—bronzite and bastite—aragonite and nitre—enargite and barite(?)—triphyllite and graftonite—barite and barytocalcite—aragonite and gypsum—astrophyllite and lepidomelane—olivine and clinohumite—humite and clinohumite—bronzite and augite—bronzite and hornblende—authophyllite and hornblende—lorenzenite and aegirite—augite and serpentine—hornblende and serpentine—epididymite and eudidymite—cordierite and muscovite—olivine and augite—zoisite and epidote—staurolite and cyanite—andalusite and cyanite—augite and biotite—hornblende and biotite—augite and hornblende—muscovite and prochlorite—orthoclase and augite and biotite—orthoclase and muscovite—orthoclase and plagioclase—arfedsonite and aenigmatite—gypsum and anhydrite.   The last pages of this weighty review are devoted to a discussion of the geometric relations of the regular intergrowths.

E. Barchet contributed a paper in 1904 upon the relations between mixed crystals and double salts.   Goldschmidt and Wright examined in a remarkable manner the solution of calcite, with various acids, and obtained some curious results; their work being directed to the delineation of etchings, obtained upon spheres.   They tabulated results from solutions of the mineral, made in different periods, as well as with different strengths of acids, and they became especially interested in the study of etchings upon devolving (*abbauenden*) crystalline structure, viz. upon a crystal structure disappearing rather than forming. • There was a continual change in the successive outlines produced by solution.   Measurements and light figures were employed in the investigation, and the results attained a surprising significance.

Hydrochloric, Nitric, Phosphoric, Formic, Acetic, Citric acids were employed, and with each acid the form of the etching changed according to concentration and temperature.

Sprockhoff of the Institute of Jena in 1904 summed up results relative to the relations obtaining between the crystal and its chemical constitution.   These were epitomized in twelve paragraphs:

(1) The presence of foreign solutes, as of Carbonate of Soda, with potassium and caesium salts, aids in the formation of clearer and larger crystals.

(2) The four salts KCl, KBr, RbCl, RbBr, crystallize in regular gyrohedral hemihedral forms.

(3) Haloid compounds of K, Rb, Cs, cleave in cubic planes.

(4) In determinations of specific gravity by balance methods, the third figures are not exact.

(5) Rubidium salts, with exception of RbCl, have a smaller index of refraction than the corresponding K salts.

(6) The relative dispersion undergoes great changes when one haloid compound is replaced by another, but remains the same when the metals replace each other.

(7) The "molecular" refraction apparently is in simple relation to the molecular size of the crystals.

(8) In the combinations of K. Rb. Cs. with Cl, Br, and I forming 6 series, the 3 members of a series are never *eutropic*.

(9) The four salts KCl, KBr, RbCl, RbBr, are *eutropic*.

(10) The iodides on one side and the caesium salts on the other are homöomorphous with the remaining members of the series to which they belong.

(11) The number relations of the quotients are, in the investigated salts, collectively rational.

(12) The double sulphate and selenate of K, Rb, Cs, are, as in the case of haloid salts, not eutropic.

The magnetic properties of crystals was later discussed by B. Bavink.

In 1905 P. Kaemmerer contributed a very difficult and exhaustive paper upon the reflection and refraction of Light in *inactive* translucent crystal plates. At the opening of this careful examination he reviewed the work done since F. E. Neumann's pioneer studies in 1835. W. Mörch reported upon the electric conductivity of Chalcopyrite, Argentite, Galena, and black Cinnabar, a text to his investigation being furnished by Faraday's observations upon the extraordinary fact of the increase of the electric conductivity of Argentite or sulphide of silver, when heated, which of course was in direct contravention of the observed loss of conductivity in heated metals, as described long before by Sir Humphrey Davy. A. Osthoff also elaborated a protracted study of the reflection and refraction of light on the twinning planes of fully transparent inactive uniaxial crystals. H. Joachim wrote upon the Interference phenomena in active crystal plates in polarized light. These optical papers were efforts to determine and visualize the complicated phases of light in its entrance, passage, or return from, crystalline lamellae. K. Mönkemeyer in 1906, contributed a series of experiments and determinations upon the formation of mixed crystals of the haloid compounds of lead, silver, thallium, and copper in fusion; the observations were made upon crystallizing mag-

mas. A. Johnsen studied twinning phenomena, and experimented with sodium uranium acetate, sodium lithium sulphate, magnesium tartrate, Carnallite, nickel ammonium chloride, nickel sodium uranium acetate, chrome-glaserite, lithium sulphate, and attempted to throw more light upon the origin and formation of twin crystals, propounding such problems as why a certain salt in certain circumstances forms twins, and why the twinning operates at different times according to different laws; he speculates upon the surfaces of increase (*verwachsung*), and on the limitation of planes (*flächenbegrenzung*). Mixed crystals and double salts continued to excite interest and Richard Nacken examined the sulphates of lithium, sodium, potassium, and silver.

Purely mineralogical papers were always forthcoming, and new species were described, new occurrences and placements of old ones, and the accumulated resources of mineralogical science applied to the description of all the aspects of a mineral compound. Among examples of very thorough crystallographic study, appearing in the German journals were E. Kleinfeldt's examination of the hematite of Dognacska (1907), of the Brazilian beryl by H. Kohlmann (1908), and interesting studies of fibrous siliceous bodies (*chalcedon, quarzin*) and their relations to Opal and Quartz.

A paper by K. Simon (1908) offered as a contribution to the knowledge of the colors of minerals, contained a variety of instructive observations. Senarmont had artificially colored nitrate of strontium, with an infusion of Campeche wood and similar trials appeared to offer grounds for believing that a large number of mineral colors are to be ascribed to organic substances. Levy thought the green tint of the emerald was to be attributed to organic impurities, though later shown to be due to chrome oxide; Sandberger found copper and manganese in the dark zircon; Wyrouboff showed that Fluorite, which phosphoresces upon heating, lost weight and detected small emitted quantities of Co_2 and H_2O, whereas Low, Moissan, and Becquerel found free fluorine in fluorite, and the last savant colored bleached fluorite and halite with an application of cathode rays. Weinschenk considered mineral colors as arising from metal oxides; L. Wöhler and K. v. Kraatz—Koschlau assumed organic pigments as their source, finding C. H. N. in zircon, smoky quartz, amethyst, celestite, fluorite, apatite, barite, rocksalt, calcite, microcline, topaz. Spezia inclined to an inorganic hypothesis and Nabe considered amethyst as colored by red iron oxide and yet later obtained from it sulphur and nitrogen.

Blue rocksalt was industriously examined, and the views of its coloring fluctuated between an organic and an inorganic source.
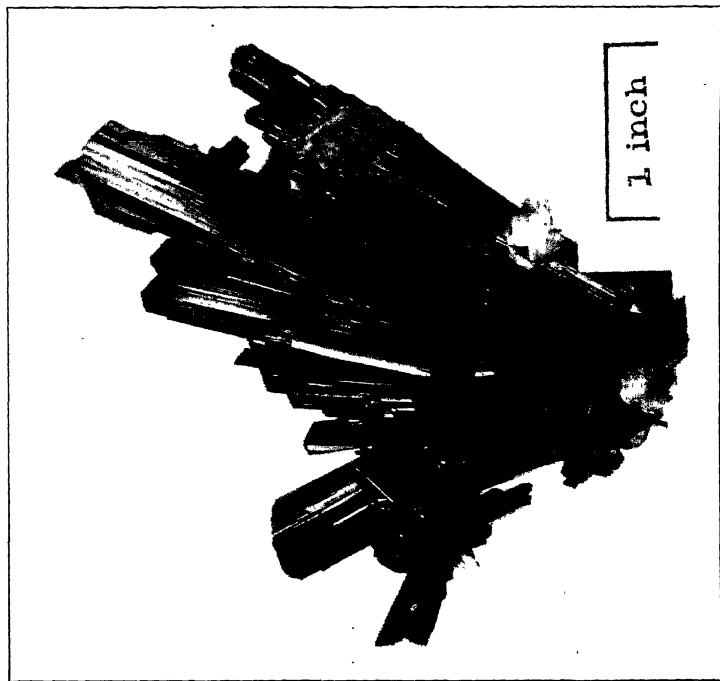
EPIDOTE
Tyrol, Switz.
Bement Collection, American Museum of Natural History
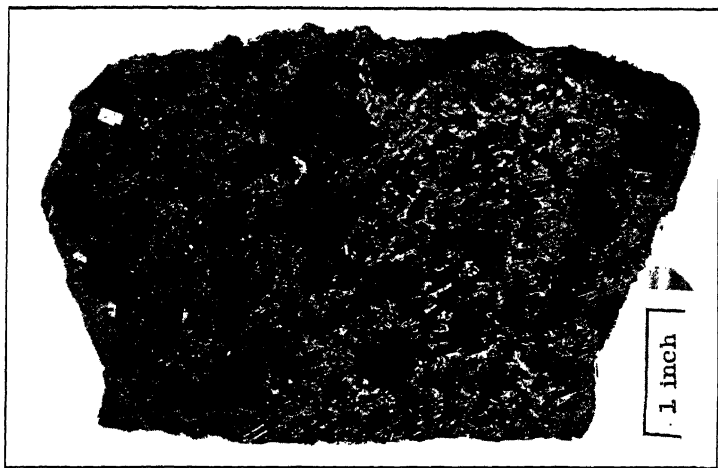
PYROSMALITE
Nordmark, Sweden

Konigsberger thought he detected in smoky quartz small amounts of Co_2 and H_2O, but these and all other determinations seemed to be brought into question. The effect of the Röntgen, Cathode, and Radium rays was studied and an actual change in color observed. Berthelot showed that upon heating to a glow decolorized amethyst resumed its color when subjected to the bombardment of radium rays. Simon took up the question but his results seem inconclusive. His general conclusions were that the change in color produced by heating does not depend upon the gas in which the mineral is heated; that the temperature necessary to remove the color is proportioned to the size of the crystal, or of the fragment experimented with; that traces of volatile inclusions seemed present, but no convincing proof established that the color was due to them.

Furthermore at high temperatures decolorized minerals when exposed to *radium* resume their color, and it is *similar* to the original color only—thus zircon treated in this way returns brown, amethyst, violet, smoky quartz, brown, red, tourmaline, red, rose-topaz, orange-red. This returned color, superinduced by the radium rays, disappears in the same way as the natural original color, and such recoloring is independent of the gas in which the mineral may be immersed: finally the *nature and state of the coloring substance is not known*.

In 1909 M. Schmidt studied the relation of the mixture of oligoclase with enstatite and augite in fusion, an important subject, but obviously related to geognostic volcanism and magmatic differentiation.

Fresnel who died at the early age of 39, transmitted in 1827 a remarkable paper to the French Academy in which he resumed papers submitted in 1821-22, in which he proposed a graphic illustration of the laws governing the transmission of rays of light in biaxial crystals. His assumption involved the existence of an elastic ether through which a ray of light was sent vibrating transversely to its direction and further postulated that "the ether of a crystal undisturbed, is a system of equal particles in stable equilibrium by reason of their mutual attractions; and that, for each pair of particles, the latter depend solely on some function of the distance between them, and act in the line joining the centers." In this etherial medium there are three directions at right angles to each other, along which there is displacement of the elastic medium, and "the elastic force due to the displacement of a single particle of ether in any direction different from the three already mentioned, will act in a direction different from that of the displacement," and an ellipsoid, thus formed, represents the transit of the light-wave in

the biaxial crystal. He assumed that the ether is virtually incompressible for the forces concerned in the transmission of light.

This was later modified, for, as L. Fletcher writes, "the theory has long been regarded as dynamically unsound; further the characters assumed for the ether, though they lead to the true wave surface, have since been found to have for necessary consequences other optical laws which are inconsistent with the results of experiment."

Huygens as far back as 1678-90 studied optical laws in crystals, as involved in the phenomena of reflection and refraction, showing that the laws of ordinary reflection and refraction of light are compatible with an undulatory theory. Malus in 1810 discovered polarization, and the emergence in doubly refracting crystals, of two planular and inter-perpendicular rays. The above was known before biaxial crystals had been discovered. The correspondence of the optical and the morphological symmetry of crystals was announced by Brewster in 1819, and in this same year Biot discovered two optical laws (1) that in the case of a biaxial crystal the planes of polarization are the internal and external bisectors of the angle between the two (?) planes which contain the ray-direction, and that each passes through one of the optic axes; (2) that the inclinations of the ray to the optic axes is constant.

In 1888 Sir Wm. Thomson took up the problem of the ether and it finally was formulated in this way: "(1) the ether is compressible even for the forces concerned in the propagation of light; (2) the actual density and rigidity of the ether is identical for all bodies; (3) the effective rigidity is invariable; (4) the effective density is different in different bodies, and in the case of doubly refractive crystals, in different directions within the same body."

The term "optical indicatrix" took on important proportions after Fresnel's work, and was a term indicating a body of revolution whose elements permitted the determination of any portion of a wave of light, travelling through a crystal, and such "indicatrix," as a surface of reference was either an ellipsoid, a spheroid, or, a sphere. "Hence" says Mr. Fletcher "if the most general form of the indicatrix be an ellipsoid, it will follow, that in the case of an orthorhombic crystal, the axes of any indicatrix must coincide with the three axes of symmetry. For a tetragonal or hexagonal crystal the symmetry of the indicatrix with respect to the general planes of symmetry requires two of the axes of the ellipsoid to be equal, and the ellipsoid to be one of revolution about the morphological axis. For a cubic crystal the symmetry of the indicatrix, with respect to the general planes of symmetry necessitates the equality

of the axes of the ellipsoid, and the surface becomes a sphere. This is true for all colors of light, though the relative magnitudes of the axes, both for the general ellipsoid and the ellipsoid of revolution may vary with the color: further it is true for all temperatures of the crystal consistent with the stability of the structure, for a plane of general symmetry must retain that character between the assumed limits of temperature."

"In the case of a mono-symmetric crystal, the induction still requires the plane of general symmetry to be a plane of symmetry of the indicatrix for all colors of light and for all temperatures consistent with crystalline stability; but the positions and dimensions of the two axes of the ellipsoid lying in the plane of general symmetry are otherwise independent of the latter, and will in general vary both with the color of the light and the temperature of the crystal."

"And in the case of an anorthic crystal, in which there is a center but no plane of general symmetry, the positions and dimensions of all three rectangular axes of the indicatrix corresponding to a given color or temperature are free from limitations by a plane of general symmetry, and will likewise vary both with the color of the light and the temperature at which the determinations are made."

These optical considerations were the occasion of an important paper by L. Fletcher being presented to the Mineralogical Society of England of which the Council reported that it "attempts to provide a new mode of treatment of the optical problems presented by crystals: the method at present in use is based on mechanical assumptions, the truth of which has never been generally accepted, and the incorrectness of which is now fully established; if the optical elasticity of crystals is really the same for all directions as, according to the latest version of the elastic theory is the case, it is clearly unsatisfactory to continue a mode of treatment of double refraction which is based on variation of elasticity, with direction."

E. Fremy (1891) published his laborious work in the artificial production of the ruby. It was in 1877 that he and M. Feil first achieved success; at first the ruby made was in sheets, lamellar and friable, but of no practical use. The color was obtained from bichromate of potash. As the alumina should be very pure, ammonia alum was calcined to obtain it: the alumina was mixed with K_2Co_3 and this mixture again with fluoride of beryllium and potassium bichromate. Prolonged calcination of the mixture at 1500° C. with circulation of moist air followed. The moisture disengages hydrofluoric acid, this appears to effect the isolation of the alumina

which has combined with the alkali or the earth, and crystallization succeeds.

Mineral Synthesis had been greatly advanced, Daubrée, Doelter, Levy, Fouqué and others contributed to this subject and elaborate speculations upon the constitution of minerals filled the journals. In 1890 F. W. Clarke and E. A. Schneider undertook to throw some light upon the correct formulæ of the silicates. Thus Talc was given the formula Mg_2H_2 (SiO_3) ; Serpentine Mg_2 (SiO_4)$_2$ H_3 (MgOH) ; Muscovite Al_3 (SiO_4)$_3$ KH_2 ; Biotite Al_2 (SiO_4) $_3$ Mg_2 R'_2 ; Phlogopite Al (SiO_4)$_3$ Mg_3 R'_3.

J. H. S. Vogt studied the formations of minerals in slags and lavas in 1891. Structural formulæ—in analogy with those evolved in organic chemical research—were evolved. R. Schauzer contributed hypothetical graphic formulæ for the organization of Orthoclase, Kaolin, Hydrargillite, Pyrophyllite, Talc, Serpentine, Brucite, Enstatite, and Clarke attacked the problem of the zeolites. Vogt in 1894 went on with his interesting inquiries into the genesis of minerals, reproducing—or trying to do so—the formation of ore deposits by differentiation processes in basic magmas.

In 1894 also Prof. Judd proved that the so-called cleavages of Corundum were tendencies to break along certain planes, due to incipient changes resulting either from the action of mechanical or chemical forces. In 1895 N. Story-Maskelyne published his Treatise on the Morphology of Crystals, which was remarkable perhaps for its admirable treatment of Symmetry of crystals. It is in this section that this paragraph occurs; crystallographic symmetry represents an abstraction, "that needs for its development and due explanation a complete science of *position,* applied to the molecular mass centers, competent to embrace not merely the relative distribution *inter se*—the *intermolecular* distribution—of the chemical molecules constituting the crystallized substance, but also the *intro* molecular arrangement of the atoms, or molecules of secondary order, whereof the molecules of the substance are themselves composed.

"Then the true significance of the ideal planes and axes of symmetry will be understood; and they will assuredly retain a place in the explanation of crystalline symmetry, since they rise into recognition directly from the fundamental principle of rationality of indices and are controlled by its consequences;" these questions had been mathematically treated by Sohncke, Fedorow, and Barlow.

Dr. A. Fock's work on chemical crystallography was an imposing contribution containing discussions of the growth of crystals, the variations arising from the concentration of the solution,
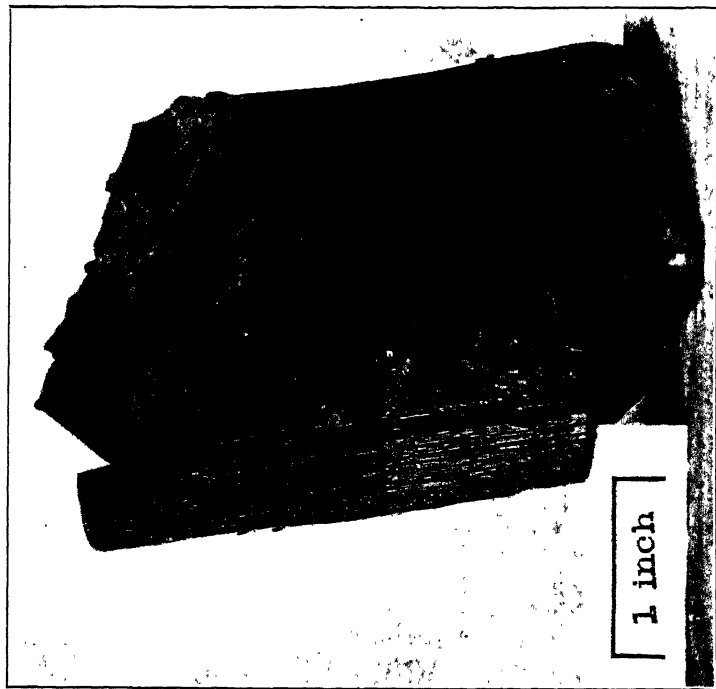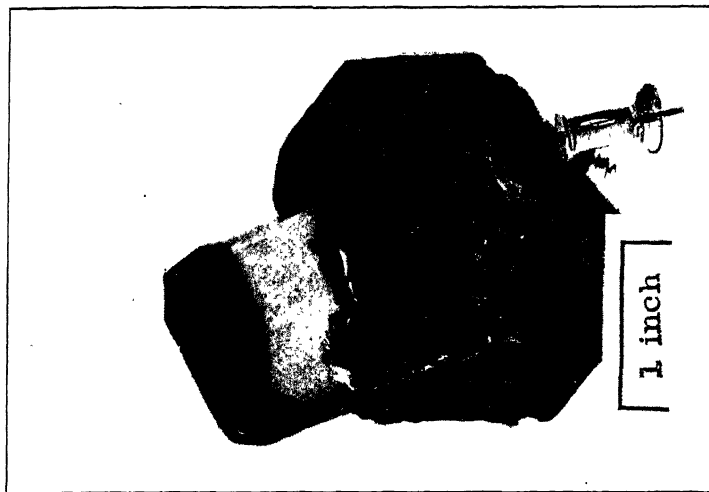
TOPAZ ON QUARTZ
Mursinka, Ural Mts.

TOURMALINE
Haddam, Conn.

Bement Collection, American Museum of Natural History

the connection of crystalline form with chemical composition, for as A. E. Tutton observed, "it can no longer be doubted that the phenomenon of a single chemical substance crystallizing in more than one crystalline form depends essentially upon a different constitution of the crystal element, the physical molecule, whether the difference is in the number or the arrangement of the chemical molecules of which it is composed."

About this time L. Michel made artificial *Powellite* and C. Friedel, succeeded in producing *Percylite, Cumengeite, Boleite,* and H. A. Miers in 1896 published an admirable paper on British Pseudomorphs, hitherto undescribed. The list has definite generalized interest and illustrate lines and fields of the enlarging examinations of mineralogical science; the mimicries recorded were, apatite after cronstedtite, calcite after quartz, calcite after celestite, cerussite after lanarkite, chalcopyrite after calcite, chalcopyrite after bismuthite, chalcopyrite after bournonite, chalybite (siderite) after bismuthite, chlorite after mispickel, copper after cuprite, erubescite after chalcopyrite, fluorite after calcite, galena and chalcopyrite after bournonite, galena after anglesite, hematite after fluorite, hematite after pyrite, hematite after calcite, hematite and redruthite after pyrite, limonite after calcite, limonite after cronstedtite, limonite after fluorite, limonite after hematite, magnetite after picrolite, malachite after cerussite, marcasite after pyrrhotite, plumbo-gummite after barite, and pyromorphite, pyrite after barite, pyrite and marcasite after pyrrhotite, pyrite after quartz and fluorite, quartz after barite, quartz after bournonite, quartz after silver and redruthite after pyrite; these interesting determinations were succeeded by a list of possible but insufficiently determined pseudomorphs comprising 56, the list of established pseudomorphs extending to 131. This continued the work of J. Reinhard Blum whose standard work *Die Pseudomorphosen des Mineralreichs* had been published more than twenty years before and whose collection of types was purchased by Yale University in 1872.

In 1900 died F. Rammelsberg, after a lifetime of extraordinary industry, in which he devoted his power of analysis and deduction to mineral chemistry his remarkable activities being more intimately concerned with the composition and formulation of the chemical construction of minerals. In 1901 the British Association for the Advancement of Science issued a report on "The Structure of Crystals" giving a full historical account of the development of the geometrical theory and in 1903 Mr. Harold Hilton discussed (1) the deviation of the 32 point-groups, which obey the law of rational indices, and has a chapter on the growth of crystals, (2)

"after establishing the 14 lattices Mr. Hilton discusses the properties of geometrical operations, and proves the fundamental proposition that each space-group is isomorphous with one of the 32 point groups, and all the operations of the point-groups are symmetry-operations of some space-lattice. The systematic application of this property determines the 230 groups." In this same year Prof. Miers issued his admirable text-book which had many novel features, and treated, almost unexceptionally, *all* of the sections of mineralogical science, with originality and clearness. Victor Goldschmidt indulged in a singular speculation in an effort to connect crystallography, music, and spectrum analysis.

A work of very deep interest appeared in 1899 by H. Vater; "Upon the Influence of other Solutes in the Crystallization of $CaCo_3$." He found that at ordinary temperatures, from a solution containing carbonic anhydride, the fundamental R was the sole product of crystallization; that the best crystals were obtained by diffusion; the method he adopted deserves consideration, "a dish 85 mm in diameter and 40 mm high was placed inside another 135 mm in diameter and 60 mm high: 1-5 gramme-equivalent of a soluble calcium salt and of an alkaline bicarbonate were dissolved in small quantities, of water saturated with CO_2, and placed in the inner and outer dishes respectively, the dishes were then filled up with water saturated with CO_2, covered, and diffusion allowed to go on. Under these conditions the crystallization of the $CaCO_3$ proceeds under the influence of the soluble salt formed by the action of the bicarbonate on the calcium salt. If it was desired to increase the amount of the co-solute or to study the effect of some other foreign substance, the compounds were added to the water." Crystals appeared round the small dish, inside towards its rim, outside, on the bottom and clinging to the water surface above. $CaCl_2$, $Ca(NO_3)_2$ with $KHCO_3$ and $NaHCO_3$ respectively gave calcite alone, in combinations of R and steep rhombohedra — mR. Addition of KCl on NaCl merely altered the values of m. The experiments were further variously modified, and the author concluded "that R is the form in which calcite crystallized from pure solution, the occurrence of other forms depending on the presence of co-solutes; the development of a particular form depending further on the nature and concentration of the co-solutes and on the *velocity* of crystallization." $CaSO_4$ seemed to induce the formation of steep R., similar sequelae followed on adding K_2SO_4, the basal plane appearing also; much Na_2SO_4 gave — mR and prisms terminating by R; Rose's statement that aragonite is not formed at temperatures below 30° C. (86° F.) was confirmed.

Handbooks of minerals, local catalogues, descriptions of species flowed on and out, and the ransacking of the earth for its mineral contents continued with unabated enthusiasm. There were new additions made to the more correct determinations of the constants of known species, new faces were added also, and better analyses published; approved methods of optical examination were applied, better shorter or more easily comprehended systems of graphic crystallography were suggested. Works like Otto Luedecker's Minerals of the Harz (appearing in 1896), Day, Allen, Becker and Idding's book on the constitution of the feldspars, the fourth edition of Groth's Physikalische Crystallographie, Lewis' Crystallography, swelled the available resources of the mineralogist's library, with many others.

Prof. H. A. Miers of Oxford took an increasing interest in the problems of crystallization and in conjunction with Jaques Chevalier in 1906 studied the crystallization of sodium nitrate, while in a remarkable address before the British Asso. Ad. Sci. at their S. African meeting he reviewed facts and principles, or laws, evinced in the formation of crystals of minerals in solidifying igneous magmas. In August 1906 Samuel Lewis Penfield died, perhaps the most wonderful intellectual combination of analytical skill, adaptive ingenuity, and synthetic power that mineralogical science had produced in America, and certainly foremost among the students of mineralogical science in the world. It would be impossible to recapitulate his contributions to mineralogy. They were most numerous, and all were marked by an extraordinary luminousness in conception and expression. Among them will be found the Branchville papers, the Franklin Furnace discoveries, the thesis on the composition of Tourmaline, "Stereographic Projection and its Possibilities," and a splendid series of descriptive investigations of the very highest order of precision. Fourteen years before this the Sixth Edition of Prof. J. D. Dana's System of Mineralogy was published in America, almost completely rewritten and enormously enlarged by his son Prof. E. S. Dana. This extraordinary work remains the standard descriptive work on minerals for the world to-day.

Crystal growth fascinated the scientific world; to touch, in it, the pulse of nature, as it were, by actual reproduction, invited extended experiment and opened up vast vistas of illumination. Among these investigators was Thomas V. Barker who had examined the regular growth of soluble salts on each other and discovered that "parallel deposition is conditioned by closeness, not of angle, nor of axial ratios, but of molecular volume." The largest isomorphous

group known is that of the double sulphates and selenates, worked over by Tutton, but the group selected by Barker for his experiments was that of the haloid compounds of Na. K. Rb. Cs. NH_4, which crystallize in the metric system. The Germans had already taken these in hand (*vide ante*); Barker's method challenges notice; "a drop of a solution of one salt was placed on a fresh cleavage piece of the other, which was viewed—on a glass slide—under the microscope. Crystals of the solute appear, as a rule in a few seconds, but the deposition is sometimes so rapid that the surface of the cleavage-flake becomes opaque instantaneously; when this happened the solution was diluted a little, but even then, with certain pairs of salts the deposition was so dense, as to prevent the attainment of a positive result."

The paper is very pleasing and full of suggestions, and, of course, defies transcription here, but the results were affirmed by the author as proving, "that in an isostructural group of substances irregular growths are only obtained where the molecular volumes differ considerably: and this holds good no matter whether the group consists partly of insoluble minerals and partly of soluble salts, or wholly of soluble salts." Later Mr. Barker continued his studies, offering a paper on The Question of a Relation between the Parallel Growths of Crystals and Isomorphous Miscibility, and the bearing of Parallel Growths on questions of Isomorphism. The opening paragraph stated that "one of the most important and striking properties of isomorphous substances is their capacity for forming microscopically homogeneous mixed crystals, the physical properties of which are, as Retgers has especially shown, intermediate between the properties of the constituents. With the great majority of isomorphous substances the mixed crystals can be obtained in all proportions, but with others the miscibility is limited." The cause of isomorphism, he believed, was to be sought in a similarity of structure "by which one means that the points at which the chemical atoms or molecules are situated, are distributed in space in a similar manner." Parallel growth apparently does not indicate isomorphism.   The author found that the "periodates of silver, lithium, sodium, ammonium, potassium, and rubidium form an isomorphous group crystallizing in the tetragonal system with similar angles to the scheelite group."

In 1908 Henry Clifton Sorby died. In English mineralogical science the names of Brewster and Sorby occupy related and equally eminent positions. From 1815-69 the former published some three hundred papers upon optical features and laws in crystals, and the latter in a lifetime, full of labor, examined the minute
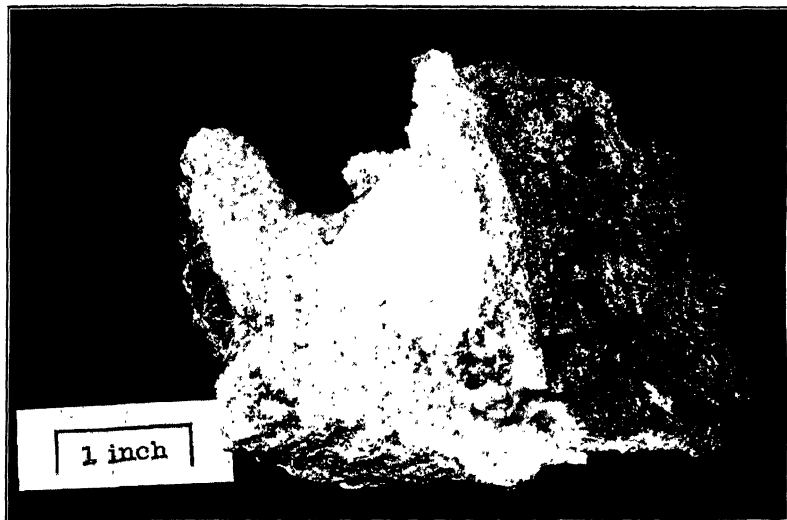
APOPHYLLITE
Poonah, India
Bement Collection, American Museum of Natural History
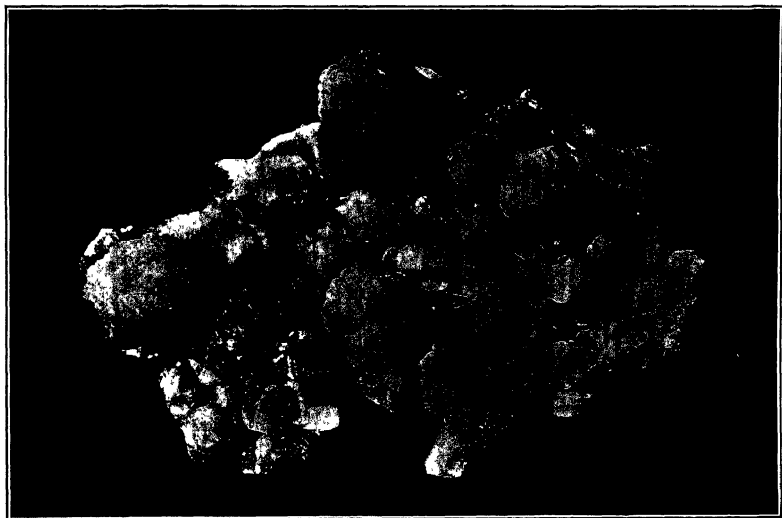
STILBITE
Iceland
Bement Collection, American Museum of Natural History

mineral construction of rocks. As Prof. Judd points out "his epoch making memoir 'On the microscopical structure of crystals'—a memoir, which, though neglected, and even ridiculed at the time, laid the foundation of microscopical petrography,—and in doing so, widened enormously the sphere of influence of mineralogy from which it borrowed so much."

In 1909 appeared Wallerant's elaborate and advanced discussion of crystal structure, growth, combinations, polymorphism, isomorphism; (*Cristallographie; deformation des corps cristallisées; groupements; polymorphisme; isomorphisme*). This work presents the advanced views of mineral science, where analysis, directed by mathematical conceptions, and guided by chemical determinations, and assisted by experiment, enters actually within the mechanism of the forming crystal and describes its growth.

Optical studies were being constantly refined and advanced, and one of Dr. Sorby's last papers (prepared many years ago) was one upon a New Method of studying the Optical Properties of Crystals, which was along the line laid down by the Duc de Chaulnes in 1767.

The brilliancy of American contributions to the science of mineralogy, has given an especial prominence to this subject in the United States. The enormous mineral resources of the country have effectively enriched mineral cabinets, and afforded the literature of mineralogy a number of classic localities for description. Perhaps generally the activity of American mineralogists has been more directed towards the description and thorough scientific elucidation of mineral species, than in more generalized or philosophical investigations of their optical and chemical relations.

The appearance of the successive editions of Prof. Dana's "System of Mineralogy" had been coincident with phases of mineralogical progress, which has made each of them not only symptomatic of a scientific era, but its reflection as well. They have, therefore, illustrated the changing conceptions of the mineralogical mind as a whole, and this cosmopolitan and liberal and practical tone recommended them to the high position they have attained as the *ex cathedra* utterances of the mineralogical faculty. In their *technique,* so to speak, they have shown the most practical and skillful arrangement of details, and their erudition has been equally remarkable and helpful. But they have also assumed the more important function of contributing original views as to the fundamental construction of the science, and this has resulted in a certain grandeur in their breadth of composition and an unmistakable forcefulness and completeness in their assertions. In the words of an English critic, "It is not too much to say that the publication of each successive

edition of this work has constituted an epoch in the history of mineralogical science." When we turn back to the edition of the "System" in 1837, and open in succession the subsequent issues, we encounter one of the interesting phases through which all branches of science have passed and which persists in a diminishing degree to-day, viz., the elaboration of its nomenclature. Too much weight cannot be given to a system of nomenclature by which the designations of the separate species are firmly determined, and the terms of their description defined; but the scope and significance of nomenclature is given a deeper importance if we extend its meaning to the classification of species, their grouping, ordinal and family arrangement. Such a problem confronted mineralogists in 1830, and, somewhat dazzled by the unexpected and euphonious results flowing from the binomial system and the groupings of genera, families, orders and classes in botany and zoology, and anxious to confer upon this science the benefits of a device which seemed the apposite reflection in language of the measures and delimitations of nature, they undertook, under the leadership of Mohs, to arrange the mineral species according to a mingled consideration of their physical and chemical composition, and with this system Dana, in 1838, combined a peculiar and original scheme of binomial titles.

Few perhaps of the younger mineralogists and none of its latest students may be familiar with this very bold and independent effort, and the occasion of the appearance of the sixth edition of this great work seemed an appropriate time to recall some of its details. It had an indelible interest as associated with the history of the science, and a still greater intellectual interest from the fact that Prof. Dana had gradually eliminated it as a whole, while preserving not only traces but representative parts of its more lucid and scientific features, features always co-ordinated with the chemical properties of minerals.

Prof. Dana, in introducing this "New Mineralogical Nomenclature" before the scientific world, said in his paper before the Lyceum of New York, in March, 1836, alluding to the system of Mohs, which he accepted: "In this arrangement M. Mohs has not wholly relied upon chemical characters, the exclusive adoption of which would have degraded mineralogy from the rank of an independent science, and merged it in that of chemistry; nor has he depended on physical characters solely; for although the latter are more especially employed, the author has throughout been guided to a certain extent by that important source of physical characters, viz., chemical composition. A cabinet arranged according to the system of Mohs presents, with remarkable clearness, a chain of affinities

running through the whole, and connecting all the several parts. The *gases* and *liquids,* with which the arrangement commences, are followed by the *salts,* so disposed as to present an increase in stability, hardness, and luster, as the eye proceeds onward. Among the *gems,* we arrive at the diamond, in which these characters reach their climax. Then descending in the series, we gradually pass through the *metallic oxides* to the *native metals.* In these the light-colored species are followed by the *sulphurets* and *arsenides* of similar color and luster, which are succeeded by the dark-colored metallic sulphurets; and these pass insensibly to the sulphurets without a true metallic luster. From the latter there is a natural transition to *sulphur,* and its close allies the *resins* and *coals,* with which the series terminates."

The minerals or mineralogical elements were grouped under the *Epigœa,* which included the fluids and all soluble minerals whose formation is now going on, the *Entogœa* embracing those which occur in rock strata, and the *Hypogœa* or those so deeply embedded in the earth's crust as to justify the appellation of buried. It was in the *Entogœa* that the larger number of the mineral species were placed. The *Epigœa* embraced gases, water, and soluble salts, as borax, alum, common salt, the alkaline salts, and the soluble secondary metallic salts, as copperas, blue and white vitriol, while the *Hypogœa* received the coals bitumens, oils, etc. These classes were again subdivided into orders, and these again into genera, and each mineral species received a binomial name under its appropriate genus.

A few examples of orders and genera from all these classes will illustrate the system without entering more minutely into details of the method.

In *Epigœa* or the mineral substances found upon the earth, we find two orders, the *Rheutinea,* or fluids, including two genera, *Aer* and *Aqua,* and the *Sterinca,* or solids, containing the genera *Acidum, Borax, Alumen, Natron, Sal, Picralum, Nitrum, Vitriolum,* and *Gœlum.* These genera were separated by considerations based upon chemical composition and upon hardness, gravity, and especially taste, as *weak sweetish alkaline, styptic, alkaline, purely saline, saline and bitter, cooling and saline, astringent and metallic.* The binomial scheme was applied in the following manner:

Genus Picralum

H.—15—2·5. G. 1·4—2·8. *Taste saline and bitter.*

P. glauberi ....Glauber's salt.
P. thenardianum ....Thenardite.
P. rhombicum ....Epsom salt.

P. reussii .... Reussite.
P. volcanicum .... Mascagnine.
P. vesuvianum ....Aphthitalite.
P. octahedrum ....Sal ammoniac.
P. deliquescens ....Nitrate of magnesia.
P. tenellum ....Nitrate of lime.

To the *Entogœa* were assigned, separated by hardness, gravity, luster, and streak, some eighty-two genera, and in looking for their determinative elements we find that they may comprehensively be grouped under chemical composition, chemical properties, as fusibility; physical features, as color, cleavage, luster; crystalline form or condition, as crystallized, massive, lamellar, etc.; geological accidents, as place of occurrence, volcanic, etc.; and associations, as granitic, etc. This system not only brought many mineral species into groups whose affinity is unquestioned to-day, and which are retained together, and must be upon any scientific basis of classification, but it also gathered into one genera very discordant neighbors and forced upon essentially distinct minerals a purely arbitrary and fictitious relationship.

Thus, under the order *Hyalinea,* so called from the high glassy luster possessed by its representatives, we find the genus *Hyalus* divided as follows:

H. bicolor ....Iolite.
H. acutus ....Axinite.
H. rhombohedrus ....Quartz.
H. opalinus ....Opal.
H. vulcani ....Obsidian.
H. sphærulus ....Sphærulite.
H. ferriferus ....Isopyre.

There was thus produced here a mixture of oxides, sub and uni silicates at the dictation of an extraneous fact, viz., luster; which, however correlated to density or molecular state, failed to express the esoteric principle which, in the philosophy of nature, establishes a truly natural classification in minerals. That esoteric principle was chemical *make-up,* which to-day rules the science and has shed such an abundant light over its dark places as to enlist it among the most finished and most rational sciences of our age. Chemical composition has been found to be the co-ordinating principle which enters most profoundly into all the varied aspects of minerals and binds into certain necessary sequences crystalline form, hardness, luster, and optical characters.

CHABAZITE
Paterson, N. J.
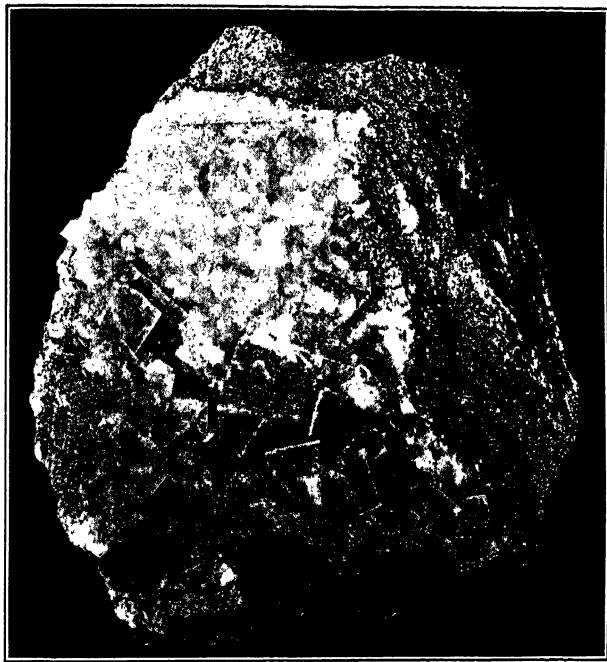
CHABAZITE
Two Islands, Nova Scotia
Bement Collection, American Museum of Natural History

The third class of Dana under this system was the *Hypogœa,* or those so-called buried minerals. In this there were two orders, *Pittinea* and *Anthracinea.* Under the first were gums, bitumens, resins, and under the latter coal and graphite. The recent large extension of the hydrocarbons could not have enjoyed its present comparatively intelligent arrangement if a system of color, translucency, etc., as here adopted, had been retained. Among these organic products, as among the inorganic species, chemistry was alone able to disperse the confusion of discrepant groupings and give to the mineralogist the guidance of her dictum as to their genealogy and kinship.

The affinities of chemical composition was the Ariadne thread which led the mineralogist through the Dædalian labyrinth of mineral species, or perhaps, less strainedly, it was the standard of reference by which they were given their natural positions. To the chemical law Prof. Dana has more and more closely adhered, while he has in this last work advanced along the line of chemical chronology and inspected, in the difficult compounds formerly classed as margarophyllites and in the micas, under the suggestions of Tschermak and Clarke, the perplexing questions of their generation from some fundamental hypothetical molecule.

This chemical plan has separated the aggregate of mineral species into native elements, arsenides, sulphides, antimonides, sulpharsenides, sulph-antimonides, and other alkaloidal unions, into the oxides, hydrous and anhydrous, the silicates, uni, bi and sub, with later modifications introduced in this sixth edition, the hydrous silicates and the oxygen salts, as carbonates, tantalates, columbates, sulphates, etc., a system practically maintained to-day, with changes more or less material in their succession and interpretation.

In the fifth edition, based upon this plan of chemical reference, Prof. Dana attacked the momentous question of synonymy, and forced upon the science a unifying device of substantive terminations, the classic if not somewhat monotonous *ite.* The review of this section of the subject by Prof. Dana in the fifth edition was very explicit and frank.

When we compare the last, sixth, edition with its immediate predecessor, we find that the science has greatly enlarged its material scope and has also changed some of its points of view. With the growth in the number of species there have been attendant consolidations of species and reference of former species to varieties. There is also shown the evidence of new light or at any rate new conceptions in the treatment of the silicates, and, to a large degree, the groupings have been rearranged, while the succession or se-

quence of groups and divisions has been extensively altered. The fundamental plan of the fifth edition has been adhered to, and it would be difficult to devise a method and typographical treatment more expressive and convenient.

In the place of the bi, mono and sub silicates with the hydrous silicates, more or less hypothetically separated under these three sections, we have the di, poly, meta, ortho and sub silicates. The disilicates are salts of disilicic acid, $H_2Si_2O_5$, and have an oxygen ratio of silicon to bases of 4:1, and are represented by *petalite;* the polysilicates are salts of polysilicic acid, $H_4Si_3O_8$, and have an oxygen ratio of 3:1, and are represented by the feldspars; the metasilicates are salts of metasilicic acid, H_2SiO_3, and have an oxygen ratio of 2:1, and are represented by *pyroxene* and *amphibole;* the orthosilicates are salts of orthosilicic acid, H_4SiO_4, having an oxygen ratio of 1:1, of which the garnets are representative; and, lastly, the sub-silicates, in which the oxygen of the bases exceeds that of the silicic acid. The system has many exceptions, and seems hardly to introduce any chemical conceptions or aid in the realization of the facts of nature more clearly than the old method, which regarded the excess of silica (as would be the case in the di and poly silicates of this system) as unsaturated acid of the ordinary type.

The species *titanite, keilhauite, guarinite, astrophyllite* and *perofskite* are considered titano-silicates, and are placed at the end of the silicates, between which and the niobates, tantalates, etc., they form an interconnecting link or at least are regarded as doing so. The carbonates precede the silicates, and quartz, which formerly ended the oxides, now, by a natural precedence, leads the list. A few substituted names or combined species for older ones strike the eye. Naselite replaces nasite, raimondite covers apatelite, lazurite replaces lapis lazuli, pinite is added to muscovite, tennantite is combined with tetrahedrite, salite takes the place of salilite, bastite or Schiller spar is put under hypersthene, jadeite receives a much fuller treatment, klipsteinite is put under rhodonite, kupfferite under anthophyllite, gieseckite under nephelite, as a long-supposed alteration product of that species. The investigation of Klein into the double refraction of garnets is incorporated, and the optical anomalies of other species, as explained by this author, also noted. Humite is separated from chondrodite, with a new species, clinohumite (1876). These three species are discussed together. Phlogopite is appended to biotite and also lepidomelane. The treatment of columbite is much expanded. Gummite and uraninite are placed under the uranates. The so-called perofskite of Magnet Cove,

Arkansas, is made a titano-niobate of calcium and iron and placed under the name dysanolite.

The crystallographic part of the system had been extensively revised. Nearly all of the 1,400 figures were either newly drawn or were new drawings of old figures, the angles of fundamental forms have been traced to the original authorities, and from them the axes have been determined by calculation, and the angles recalculated of the more important and common forms. The numerous interpolations of new species had displaced the old species from their numeral position, as well as their rearrangement. The vast amount of mineralogical investigation which had accumulated in recent years had been examined, and its substantial and permanent results given.

The sixth edition of Dana's "System of Mineralogy" placed the science of minerals in a unique position, for it furnished the student with a text book which was practically a complete repository of all that the science contained.

Along with development in the philosophy of mineralogy went constantly new and improved devices for increasing the accuracy of test and observation, and more complete tabulations of results. Among such may be reckoned the development of two-circle measurements for crystal faces by Goldschmidt, and this crystallographer's analysis of probable forms in any system. The vigilance and penetration of crystallographers was one of the features in the development of mineralogy. Nothing now escapes them and their precision reveals nature's secrets (even her evasions) unerringly.

In recent years the physical characters of minerals have been subjected to searching experimental tests, and this has tied more closely Mineralogy to Lithology and, in certain aspects, to Geology. The work done by Vogt has attracted world-wide attention, and at the Carnegie Geophysical Laboratory at Washington, Allen, White, Wright, Larsen have extended the studies of Mallard and Le Chatelier. In this class of investigations, for instance, Wollastonite, the silicate of calcium, is found to be stable up to $1190°$, when it reverts to a pseudohexagonal form (alpha form) melting at $1512°$, while the fact that Quartz exists in two enantiotropic forms α and β—the former below $575°$, the latter above that temperature—has proven serviceable in determining past geological conditions.

Alpha Quartz crystallizes in the trapezohedral-tetartohedral division of the hexagonal system; the high temperature β form, stable above $575°$, is also hexagonal, but in all probability trapezohedral-hemihedral in its symmetry, the axial ratio of the two forms being however very near identical. Quoting Wright and Larsen,

"at ordinary temperatures all quartz is α-quartz, but if at any time in its history, a particular piece of quartz, has passed the inversion point, and been heated above 575°, it bears ever afterwards marks potentially present which, on proper treatment, can be made to appear, just as an exposed photographic plate can be distinguished at once from an unexposed plate on immersion in a proper developer, although before development both plates may be identical in appearance."

In Dr. C. Doelter's Physikalisch-Chemische Mineralogie (G. E. Stechert & Co.) is a compendium of explorations into the physical properties of crystallizing bodies with reviews of investigations in polymorphism, isomorphism, morphotropism, the interdependence of crystal form and chemical composition, of the relation between hardness and chemical composition, of the melting point, and heat, of rock-forming minerals, the nature of silicate fusions, rapidity of crystallization, and the conditions of fused, or liquid, silicates. Under this latter heading are found the influence of mineralizers; influence of lowering the melting point; on the formation of polymorphous species; the influence of concentration; the influence of viscosity upon the probability and rapidity of crystallization; influence of water; catalytic action; differences in the point of separation; and the influence of this upon the chemical equilibrium; observations on the mixed fusion of silicates; stability of silicates at high temperatures; influence of rest; the order of separation of minerals in rocks; artificial fusions; interdependence of points of separation and melting; influence of the melting point upon congelation sequelae; dependence of the order of separation upon chemical composition; dependence of order of separation upon molecular volume; Vogts' theory of the retardation of silicate-formation through an excess of silicate of aluminium.

Further sections discuss, the volcanic magma; formation of crystalline schists; metamorphism of sediments through pressure; sublimation (pneumatolytic mineralization); zeolites and hydrates; water solution; growth of crystals; solutions of minerals in nature; solubility and formation of minerals.

One of the very important contributions to Mineralogical Physico-chemical speculations in recent years has been A. L. Day's and E. T. Allen's examination and discussion of the Isomorphism and Thermal properties of the Feldspars. This was practically a demonstration of the validity of Tschermak's theory that the feldspars, excepting the potash feldspars, (orthoclase and microcline), represented isomorphous mixtures of the soda, (Albite), and the lime, (Anorthite) feldspars, with the pure molecule of albite at one
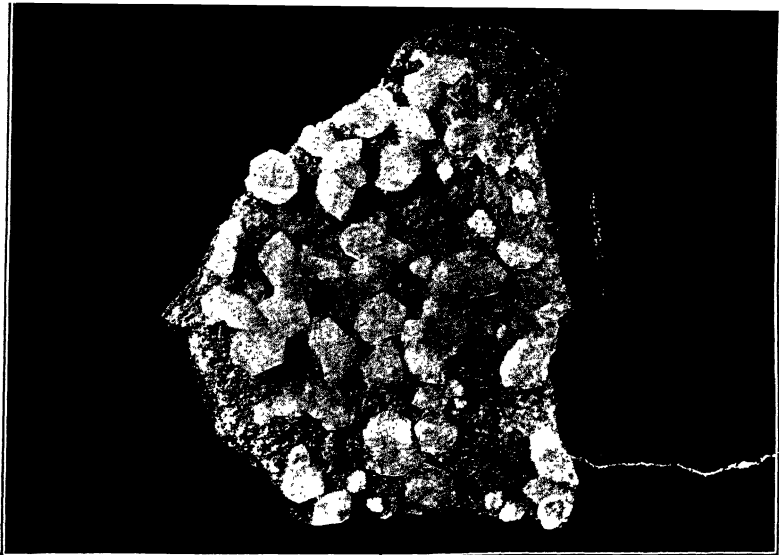
CHABAZITE (Phacolite)
Melbourne, Australia
Bement Collection, American Museum of Natural History
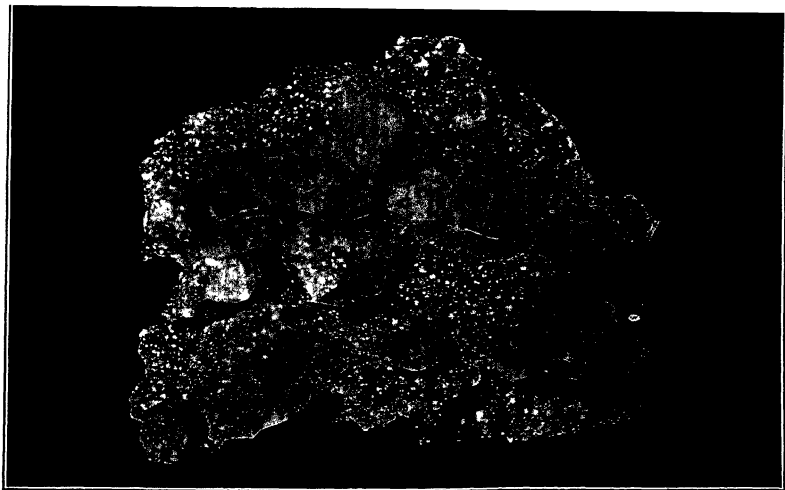
ANALCITE (with Apophyllite)
Keweenaw Co., Mich.
Bement Collection, American Museum of Natural History

end, and the pure molecule of anorthite at the other. These investigators prepared artificially the albite salt, and the anorthite salt, and they made intermediary mixtures in which from anorthite to albite the percentage of the lime molecule gradually diminished and that of the albite increased, as An 100; Ab, An_5; Ab, An_2; Ab An_1; Ab_2An_1; Ab_3An_1; Ab 100. The conclusion of prime importance, associated with a variety of most useful detailed observations, was that "if the melting point were plotted in a system, of which they form the ordinates, while the percentage composition of the different feldspars form the abscissas, we discover, within the limits of accuracy of possible measurement at these temperatures, a nearly linear relation: the melting point varies very closely with the composition. We have no maximum, no minimum, no branching of the curve, but from each fusion there separates a solid phase of the same composition as the vitreous matrix." The term *solid solution* has now practically been allotted to cover such blends of mineral molecules, and Fenner has suggestively introduced the conception in the zeolites, as in a progress from *natrolite* to *scolecite* or *chabazite* to *gmelinite*. (Day and Allen's complete study will be found in Publication 31, Carnegie Institution Washington, and its epitome in the American Journal of Science, Vol. 19,—p. 93,— 1905.)

The Bement Collection of Minerals

It would be of great service to mineralogical science if some sort of descriptive catalogue of the very important collections were prepared and illustrated, so far at least as to permit a succinct re-presentation of their valuable or conspicuous features. Apart from the fact that Mineralogical Collections of commanding interest are widely separated even to the extent of oceanic and continental limits, it is very clear that no one can remember the specific or detailed aspects of a collection, after he has left it, and some sort of a reminder, more authentic than his own hap-hazard notes, will always be helpful.

The preparation of such illustrated descriptive catalogues also gives a public permanency to the specimens, and involves very attractively the art of the photographer or delineator in their reproduction. It is quite certain that had the Shepard collection of Minerals, destroyed by fire, been given a literary and figured record, Mineralogy would have been benefitted, and something more tangible than shadowy memories of its salient features replaced such dim and purely personal chronicles.

The Bement Collection of Minerals is one of just celebrity, and in the quality of its contents, the average beauty, in some cases, the unique perfection of its specimens, secures a deserved eminence. It is a collection naturally, which abounds in very beautiful and very rare and scientifically precious mineral examples. It represents the sifted and compressed results of a lifetime of collecting, in which the widest latitude of liberal appraisement of specimens has been met on the part of Mr. Bement by as boundless a generosity. There can be no question as to its importance. Its present position in the American Museum of Natural History in New York City is of incomparable value to all students and collectors and dealers. It is placed in a central, accessible, and finely equipped stadium. It can all be seen, well seen, and seen at all times. Emerging from the privacy of a collector's study—although it is well known that Mr. Bement at no time displayed a spirit of parsimonious possession—it is now installed under favorable circumstances for visitors of all grades and qualifications.

Mr. Bement has furnished investigators with abundant material, and his friends, who were the leading students of this subject, have had only too many occasions to praise his hospitality and liberal

use of his scientific treasures. But from the nature of the case a collection housed in drawers is quite differently related to the community of mineralogists from a collection placed in a public hall in a free museum under unexceptionable circumstances of light and access. This changed condition has but one unfortunate aspect; it does mean in time, I think, a sensible deterioration of the collection in point of color value. I have noticed that specimens even of vanadinite, descloisite, and rhodonite, lose something of their initial brilliancy and intensity under the scourge of that actinic bombardment to which they become exposed in our halls. The fluorites, pink quartzes, even the delicate greens of some spodumenes, the faintly blushing calcites and the rhodochrosites, also sensibly succumb to these exposures, while it is a matter of common annoyance to find that the realgars, cerargyrites, proustites, cuprites, crocoites, and sulphurs go through changes that slowly alter their substance, texture, and appearance. Stibnite loses its splendent surface, cut topazes pale, and some colors in barite slowly vanish. Mercury minerals are altered, Cerargyrite changes and Andorite tarnishes.

With these drawbacks considered, and making allowances for the long time required for these painful processes to become perceptible, and the further fact that in most cases some small expenditure of money can restore the injured specimens, we can all rejoice in the public position now vouchsafed to this extraordinary collection.

If we examine the Bement Collection more particularly with reference to its mineralogical interest, we find the representative minerals very strongly presented. The sulphides, antimonides, arsenides, the oxides, the carbonates, the silicates, the sulphates, phosphates, chromates, tungstates, etc., are prominent, but all the larger divisions of the mineral groups secure adequate representation. When we more narrowly inspect the collection with reference to the exhaustive presentation of a species, we find that it is perhaps more remarkable for the beauty, the extraordinary perfection of individual examples, than for a complete incorporation of the many aspects of a mineral in the crystallographic and paragenetic fields of mineral discussions. Individual species, as proustite, galena, fluorite, pyrite, quartz, hematite, rutile, calcite, azurite, the feldspars, beryl, garnet, topaz, tourmaline, the zeolites, apatite, claim prominence for the superb examples they present of these striking and popular minerals.

This extended character of the collection is well illustrated in other sections as well, and while the cloud of varietal names and

substances do not appear so elaborately developed as perchance in such a collection as that of Mr. Roebling's, the comprehensive character of Mr. Bement's cabinet is unmistakable.

The scope and contents of such a description as is aimed at here, and even the degree of fidelity with which it adheres to the stereotyped character of a description as ordinarily defined, admits of a very varying expression. The limits naturally expected between a purely popular and gossiping account of the collection, and the other extreme of exhaustive scientific study and analysis can ordinarily not be accomplished by the same hand with equal facility, nor embraced in the compass of the same work.

The present author has no hesitation in confessing his inability to adequately note all the crystallographic novelties of this extensive series of minerals and in that form of erudition this description will be more suggestive than convincing. Neither will this paper substantially observe all the specimens in the collection. It aims to give an accurate impression of the contents of the collection only. For such further amplification as seems instructive or entertaining there seems no reason to offer either explanation or apology.

Illustration of such a collection is desirable, but difficult, and it partakes, in the same measure as the description, of the extremes of scientific precision or merely pictorial interest.

The order here followed, adheres strictly to the order of the exhibition in the collection, which is that of the sixth edition of E. S. Dana's monumental work.

The photographic work involved many troubles. The difficulties are obvious. The translucency or transparency, the soft open or dense texture of minerals is certainly not easy to simulate in a photograph with complete realistic effect, while in multiple aggregates of Crystals to catch just the right angle of illumination that will bring forward sharply the edges, faces, and intersections, is a task of puzzling calculation, and demands a slight degree at least of technical information in the science itself. And yet it can safely be imagined that a photographer of artistic temperament will clearly enough appreciate, without any training in purely mineralogical knowledge that there is a difference in the chalky surface of a white aragonite from the reflecting surface of a quartz crystal, that the many flaws, feathers, and cracks, opacities and clear spots in some gemlike prism of beryl, can be photographically differentiated from the surface irregularities and hard expression of a big brown garnet or a mass of corundum. In a measure the lens of the camera, and the sensitivity of a photographer's plate will help to make these distinctions, but beside that, the discerning eye and the responsive

technique of the artist must also be serviceably called into requisition. The attempt to introduce color into figures of gems and gem material has, as we all know, been tried with results that must make "the judicious grieve." The elusive delicacy, the gem texture, the interior lights, changeable and interblending seem hopelessly lost, and in place of the fascination of the colored stone we have a hard commonplace patch of admixed or continuous pigments.

In photographing minerals these points appear of predominant importance: (1) Definition; (2) Texture; (3) Illumination.

Definition is certainly a distinct and unavoidable necessity. The beauty of crystalline structure is quite lost in blurred outlines. But definition in large subjects, where there is an appreciable depth and height to the specimen, is not so easily attained; that is exquisite minute definition. Generally speaking there seems but one way to secure adequate results in this direction. Use an all round rectilinear lens of rather long focus, and after getting a clear sharp focus upon a printed slip-skeleton letters—to be preferred to double leaded or gothic type—placed first in the center, then at the front, then behind the specimen, and, if the specimen is high, also at the top and bottom, and dividing the focus thus obtained, if it is necessary or possible, insert a very small diaphragm, perhaps smaller than any your lens is provided with, and take the picture. No process of sharpening, as every one knows, but many fail to remember, compares with this method of excluding all the light but the direct rays. The time of exposure is of course greatly lengthened, but time is of no account and can be liberally used. The edges will be sharp, the faces clean and clear, and the intricacies of the crystal may be displayed.

Texture involves something less mechanical than definition. The operator must have a feeling for it. Glass is different from wood iron from biscuit ware, and so in minerals there are very apparent textures, and the charm of a photograph is to give the beholder the sensation of this texture. I should say generally that in translucent and transparent subjects a background should be used which, while it relieves the subject, also reflects light back through it, and brings in view its interior imperfections, clouds, *nuances,* inclusions, and reflections. And further that in the case of hard dense opaque masses or crystals, side lights reflected from the faces of the specimen should be carefully employed.

Illumination must in the third place be penetrating and adequate. In mineral specimens the bases of crystals often interlock, and form small cups or depressed areas, while from the accidents of intersection a great many places in a mineral specimen are in shadow.

This point is one in which some difference of opinion would natural-ly arise. All possible illumination not inconsistent with giving the specimen relief, body, and perspective, should be used. I recom-mend the use of small hand-mirrors which can be so employed so as to reinforce the bases of the crystals, the intersections, and the hundreds of details in the surfaces, as pits, striations, etc.

Certainly these are all vague hints, but the field is an inviting and a rather untrodden one. Beautiful results may sometimes be attained. There is something to be said about the selection of speci-mens. This is by far the lightest part of the task. Some specimens seem made for the photographer; others defy his skill. Of course choose the former. And finally, but far from least, is the question -of development and time exposure. I am not going to dwell on these, except to say that slow development is advantageous, and *over development ruinous,* and that exposures should be generous.

The photographs made for this chapter were nearly all pre-pared by Mr. Milton G. Smith.

Very remarkable results in the definition of detail have been attained lately in Washington, in the work of the United States Geological Survey, where minerals having lustrous reflecting sur-faces have been exposed to the combined vapors of chlorine gas and ammonia. The interaction of these elements is instantaneous and a frostlike precipitation of sal-ammoniac ensues, which cuts out the disturbing effects of reflection, producing a dead gray or white surface in which the surface features are revealed, and the photo-graph reproduces with surprising fidelity the linings, terminations, pittings, and minor irregularities, as well as the less easily rendered crystal modifications. Plate Z, illustrates an example of this work. It was made for Mr. W. T. Schaller of the U. S. Geological Sur-vey and the subject was a Bruce purchase, a group of thin tourma-line crystals confusedly developed, terminated; with white prisms and pink cappings. It makes an admirable demonstration of the process, though producing a rather odd whitish effect.

The qualifications of a good collector, in any department of science or art, presupposes an excellent understanding of the sub-ject involved, and a personal faculty of comparison and discrimina-tion. Superadded to understanding and judgment, a kind of sen-sitiveness to beauty is indispensable for the best success, if the objects of acquisition possess the charms of color and form. In scientific collecting the scientific sense developed into an appre-ciation, at least, of the varied aspects of a scientific topic are con-clusively of vital importance. A collector must have patience, per-severance, active and industrious designs upon dealers, his rivals,

TOURMALINE
Pala, Cal.
American Museum of Natural History

and the sources of production, which latter are, with the art collector, the bibliophite, the histriographer, etc., the centers of culture; and, with the scientific collector, the quarries, mines, and accidents of nature.

In mineral collecting there is obviously conjoined appreciation of beauty, and knowledge of form, and for the more comprehensive collectors a recognition of the uses of a mineral, its phases, and varieties, and the relations of a mineral to rocks as a rock constituent, as well as the relations of minerals to each other in their associations, intergrowth, and pseudomorphism, and the varying habit of different localities.

The limitations of space usually preclude any collector, less universal in his aims than a museum, from occupying his attention with all these aspects of mineralogy, and the most natural pre-eminence, in mineral collecting, is secured by a strict adherence to physical perfection and completeness, this latter having reference to the possession of the entire catalogue of mineral species. In all this it is tacitly assumed that the financial limitations of the collector are at no time embarrassing or obstructive. With reference however to the cost of making a collection, it is quite surprising what admirable and instructive collections can be made from fragments, bits, grains and minute crystals. Specimens, which appear contemptible to the unaided eye become under a magnifying power wonderfully beautiful, while from the very fact of their diminished areas of growth they reach the limits of crystallographic perfection. Some of the interesting illustrations of calcite and datolite, obtained recently by Prof. H. P. Whitlock of Albany were observed in very small specimens, and similarly the extraordinary results attained by Schaller in the Terlingua mercury minerals.

Extreme individual beauty of the specimens, in some cases amounting to almost a monopoly of the finest extant specimens of a species, as regards locality, characterizes the Bement Collection. In point of exhaustive representation of the mineral series it does not compete in this continent with the Roebling or Ferrier collections. The latter collection which has lately passed into the possession of the McGill University in Montreal, and was in charge of Prof. Harrington until that gentleman's lamented death contains over 700 of the 820 species—excluding the organic salts—in the main body of the Sixth Edition of Dana's System. But in the elegance of well selected groupings and associations, exquisite finish and beauty of individual crystals, it seems definitely proven that no collection of this country rivals the perfection of the Bement Cabinet. It is, of course, strictly mineralogical, and the geological and economic aspects of minerals are disregarded.

plates, with surfaces curiously lined, pitted and scored, apparently impressed by the crystallizing calcite; one exquisite specimen, in octahedral elongation in arborescent shapes and surfaces minutely triangulated; flattened blades, surfaces blistered in blebs, as if melted, and a surface webbed with lines. The variations are full of interest. One rhombic-dodecahedron laminated, with seamed edges and hollow faces, comes from the Comstock Lode, and a specimen (given by Miss Bruce) is a crystallized silver enclosed in datolite.

In **Copper,** the Bement Collection has always been renowned, and a short inspection shows its extreme excellence, from the beauty and crystallographic interest of the, not over numerous, but wisely selected specimens. There are in the collection interesting groups from Australia, a number of excellent examples from Cornwall, the familiar pseudomorphs from Corocoro, Bolivia, after Aragonite, and those after azurite from New Mexico, admirable aborescent and dodecahedral specimens from Bisbee Arizona, octahedrons from Arizona, but naturally the Michigan coppers claim pre-eminence, and have received distinction from the studies of Prof. E. S. Dana. Clean strong tetrahexahedrons, with cube, the rare tetragonal trisoctohedrons, rhombic dodecahedron, unions of d and e, an apparent rhombic-dodecahedron encased in later depositions of copper (431), hollow crystals (434) twins on datolite, a remarkable distorted e enclosing calcite, or else a pseudomorph after calcite many of the curious hemihedral tetrahexahedrons that look like low hexagonal pyramids, are seen, while magnificent crystallizations in larger masses appear in profusion. One interesting specimen (484) is made up of angularly disposed plates surrounding quartz, which has left hexagonal impressions; another (489) is a field of cubes in diminishing branching arms, while in 490 occurs the rare combination of o and d, and fine illustrations of the possible pseudomorph after laumontite are present. Mr. Bement has gathered specimens of the early collections, 1873, and has been indebted to Mr. Cahn for additions made in the 90s and while there are splendid series in Boston, Philadelphia, Washington, and Chicago, to-day,—and especially at Calumet Mich—the coppers of this collection generally, in detail, and in their collective beauty probably would be assigned a high place.

Elements—Species 26—Specimens 415

In the second great division of the mineral species, the Sulphides, Arsenides, etc., and their various unions, the Bement Collection offers a strong and very satisfactory representation, at least as regards the prominent or typical members of this class. No exhaustive analysis is intended, nor could be attained in this sketch.

A valuable and even remarkable series of **Realgars** forms the introduction to this section. The Hungary specimens are the gems, and amongst these No. 608 with prism, pinacoid, and hemi pyramids perhaps merits the first place, and in 619 an almost startling effect of color and placement is revealed, in a chain of crystals crossing diagonally a plate of quartz. The **Lorandite** from Macedonia, associated with Realgar, is admirable.

The vexed question of the finest collection, extant in this country, of the Japanese **Stibnites** can hardly be settled by reference to the Bement Cabinet, very beautiful and superb as are the examples in it of these extraordinary crystals. No. 642; two bifurcating crystals, 8 to 9 inches long; the composite eleven inch crystal of No. 643; the beautiful fluted terminated group, No. 645; and the stout crystal, No. 646, with its complex termination forming a rounded apex, together with some glorious wall-case groups, claim admiration. Very interesting Hungarian Stibnites, which, before the Mt. Kosang development, so readily took precedence in collections, provide reminiscent suggestions. Here also are the singular twisted stibnites from California.

The Canadian Molybdenite was secured we believe, from Dr. Foote, and exhibits some very favorable first selections, but of even greater interest are the New Jersey examples, embedded in mica, and looking like miniature polygonal barrels on their sides. These are unique.

Argentite obtains a very fine representation; the crystallizations are superior, embracing a, o, d, p, n, in combination. A delicate specimen, of cubes perched upon slender peduncles, from Annaberg, Saxony is especially curious and pretty; a large cube from Sardinia, with o faces, in barite with quartz, and the Mexican and Colorado specimens all repay a closer examination than can be made through the glass cover of a case, especially the cubo-octahedral example from Silverton with its curved edges (a Cahn purchase).

If we pass over the intermediate species, and examine the large suite of **Galena,** the eye is impressed with the skill and resourcefulness of the collector. It represents generous and continuous selections. There are about one hundred and thirty hand or case specimens, and nearly every one of these possesses individual interest, many of them are extremely beautiful, and many almost unique. Here is one from Gonderbach Germany, a cube flattened into a plate and truncated by the octahedron, not a rarity from this locality but a very captivating example, and it is only one of

a goodly series of distorted cubo-octahedrons from Germany; the curious pseudomorphs after chalcopyrite (No. 890), octahedrons pitted with calcite, cubes from Rossie with peculiar wrinkled or shagreened faces, the cubo-octahedron, Joplin Mo., with curious secondary crystals protuberant at angles, or truncation planes, malleated cubes, distortions, reticulate structure, elongations, parallel growths, compressed and intersecting crystals, skeletons, twisted and produced cubes, eroded or cavernous faces, are amongst the series of diversified and instructive lead sulphides. A handsome arsenical galena (*Steinmannite*) from Bohemia may be mentioned in passing, being a truncated cube; cube faces pitted.

The Cornish **Chalcocite** cannot be expected to rival the superb sets in the British Museum, but they are very striking. Twinned crystals, crystals with predominant domes, tabular crystals, a pseudomorph after pyrite, well developed typical crystals, with pyramid base and dome, alterations to cuprite, an old St. Just specimen, tabular, with the surfaces of the crystals papillose with projecting individual crystals, twinned prisms, curious densely crowded pin point crystals, large tables, etc., are amongst the many fine features of this suite.

At this point occurs four superior specimens of *Sternbergite,* all from Joachimsthal, with a cubical *frieseite,* var. of Sternbergite, also *argentopyrite,* which, by reason of its doubtful crystallographic position, would repay study. There succeeds a few remarkable Acanthites with one *daleminzite* of interest.

The **Sphalerite** can be omitted in this brief survey, for while there are admirable specimens, it does not awaken so much surprise as other sections; it includes some good ferriferous material (marmatite). There is a superb twinned **Tiemannite** from Utah and also fine twinned and tetrahedral Alabandite. In **Cinnabar** No. 1357 from Mt. Avala Servia reproduces Dana's Fig. 4, p. 67, in the System, sixth edition; indeed Nos. 1358 to 1366 are remarkable exemplifications of Cinnabar crystallization, and the crowded cauliflower heads produced by intersecting rhombohedrons are certainly curious, from Napa Co., Cal. Tabular *Covellite* from Luzon, a cubical pseudomorph of the same; good *Greenockite* pyramids, others, hemimorphic, showing pyramid, prism and base, implanted minute pyramids on prehnite from Scotland; long trigonal needles of *Millerite* in calcite; hexagonal *Niccolite* merit prominence before the Pyrrhotites are encountered.

In **Pyrrhotite** excellent crystals are seen, from Saxony, Carinthia, Brazil, Maine, and Tilly Foster (these, acute six-sided pyramids); the series is admirable. It would be expected that

Chalcopyrite with its strong and interesting habit would receive from so accomplished a connoisseur as Mr. Bement very considerable attention. The expectation is not disappointed. Splendid sphenoids from Kapnik, scalenohedral modifications, twins, pseudo-tetragonal habit from equally developed sphenoids, glorious Cornish specimens, a brilliant example from Chili, Ellenville twins with prism, the French Creek beauties, Missouri and Colorado specimens complete a very conspicuous display.

Pyrite, like all abundantly distributed species, is apt to appear in collections in excess. It is significant of the taste and insight shown in this collection that in this most common species the duplication is greatly reduced. Perhaps at only two points in the whole collection Chondrodite and Colemannite, do the specimens seem excessive and repetitive. At any rate the Pyrites are a reviewed and very deliberately compared group. The crystals are varied and interesting, and those, of course, from French Creek, described by Penfield, classic. It is out of the question to enumerate the details of this species. First come the Italian specimens, a brilliant selection in perfect condition, those from Brosso showing a, o, e, m, s, unrivalled individuals from Traversella, amazingly strong and expressive groups from Rio with cubo-octahedrons, twinned pyritohedron, etc. The Swiss pyrites follow, then the Austrian, the Swedish, the French, the Bohemian, with varying habits, the English, and finally the American. Considerable interest attaches to these last, with the preeminence in the Pennsylvanian and Colorado series. No. 1736, a distorted octahedron, with striations and triangular markings is a remarkable specimen from Franklin N. J. The French Creek specimens are embraced in Nos. 1747 to 1771, amongst which is the famous elongated octahedron (No. 1757), *said* to have been sold to Dr. Foote for $150, and which has been interpreted as a distorted trigonal trisoctahedron with diploid and pyritohedron. From Gilpin Co. Colorado are a fine series of lustrous pyrites; No. 1804 a flattened cube with intersecting smaller individuals, delicately striated; and then the superb d faces on the cube; and the beautiful individuals from Montezuma, which attain such complex development, as in No. 1823; the o and d combination in 1828, and the faultless groups 1836, 1837.

From Pyrite to the end of the sulphide and arsenide series occurs the bewildering succession of species so well known to mineralogists, and amongst which in the Bement Collection mineral gems are liberally distributed. Here are placed the wonderful Raddusa *Hauerites,* excellent *Smaltite* from Saxony, the Swedish *Cobaltites,* an unusual cubical *Gersdorffite,* beautiful *Ullmannites,* crystals of

MUSCOVITE
Pennsbury, Pa.
Bement Collection, American Museum of Natural History
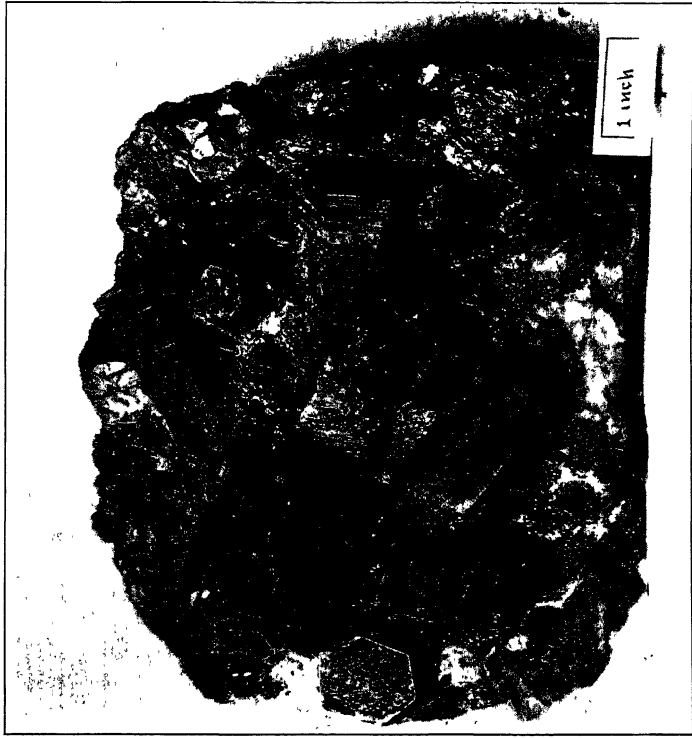
PHLOGOPITE
Sterling Hill, N. J.
Bement Collection, American Museum of Natural History

Laurite, cubo-pyritohedral *Skutterudite,* and many *Marcasites,* perishable but attractive.

Arsenopyrite is well represented with a notable specimen from Cornwall (2065), and strong crystallizations from Saxony, and some twins and elongated crystals of the cobaltiferous *Danaite.* The **Glaucodot** crystals are large, well developed; 2088 shows three intersecting crystals, domes and prisms, of high quality. The tellurides are expensive treasures for the mineralogist, if the finest specimens are sought for, and the Bement Collection boasts of some splendid individual *Sylvanite, Calaverite, Krennerite,* and *Nagyagite.*

As the eye moves over the rapidly succeeding species, it encounters many surprises; here is a thin (pinacoidal compression) crystal of *Guejarite,* crystals of *Zinkenite,* clear single crystals of *Miargyrite,* large crystal of *Binnite* with a, o, and n, *Dufrenoysite* in a prism with domes well developed, a striking *Diaphorite* in a divergent group of crystals on siderite in a galena cavity, a superb *Freieslebenite,* from Spain, and the impressive galaxy of *Bournonites,* though the visitor may regretfully recall the same species in the British Museum collection. But these are worthy of attention— especially Nos. 2238, 2244, 2260. The *Pyrargyrite* and *Proustite,* can be passed without especial notice, beautiful and satisfying as they are, because of their general representation in collections, and because any detail would too greatly extend this notice. In Pyrargyrite Nos. 2290, 2293, 2295, 2297, 2302, 2303 deserve attention, and in Proustite Nos. 2310, 2316, 2321, 2327, 2330, 2332, 2334, 2335, 2337, 2338, 2342 are important.

No. 2353 is a *Rittingerite* from Bohemia showing hyacinthine prisms on galena; of course there are typical *Tetrahedrite* and *Tennantite* which, in No. 2422, shows as minute crystals encrusting tetrahedrons of chalcopyrite; near at hand is a rare *Polytelite* and a *Clayite* crystal.

The handsome Binnenthal (*Jordanite*) specimens will attract notice, and no less the remarkable examples of *Meneghinite;* **Stephanite** is strongly represented; note 2443, 2444, 2446, 2448, 2451, etc. The series closes with fine *Polybasite,* and *Enargite, Lautite, Famatinite, Epiboulangerite, Xanthoconite, Clarite, Argyrodite.* Species. 174. Specimens. 1450.

The next step in this review brings us to the Haloid Compounds and Oxides.

HALOID COMPOUNDS AND OXIDES.

In the combinations of Chlorine and Fluorine with the bases, Nature produces some of her most tasteful results. In color her

palette has given to the mineral Fluorite a wonderfully expanded range of tints, and though the crystal forms of this group of minerals are on the whole quite simple, yet their legible presentation, in isometric species, places them in high esteem with less erudite mineral collectors.

This section in the Bement Collection opens with *Calomel*, the chloride of Mercury, from Moschellandsberg and Servia. The finest examples are from the latter associated with cinnabar and mercury. The form is familiar, low and columnar tetragonal prisms and pyramids, those from Moschellandsberg sometimes with many faceted apices. In the Bement specimens the finest are from Mt. Avala, Servia.

Halite follows from Galicia, in excellent cubes, typical and elongated and flattened into plates; with the vivid blue spotty inclusions and centers in others from Stassfurt, a beautiful fibrous mat, exquisitely colored with a violet tint, from Hallstadt, and a pseudomorph after Sylvite showing the cubo-octahedral combination of faces. A series of the remarkable distorted octahedrons from Humboldt Co., Nevada, showing also the union of cube and octahedron, the peculiar blistered and nodular surfaces, with the smoothed, apparently dissolved inequalities of faces are well selected.

Two specimens of the double chloride of sodium and silver (*Huantajayite*) from Peru occur, in minute encrusting crystals in a seam, in metalliferous rock.

Sylvite is represented by excellent examples from Stassfurt; and *Sal Ammoniac* in crystals of the cube and octahedron united, on projecting pedicels, from Mt. Vesuvius. **Cerargyrite** from Chili furnishes crystals, and a remarkable mass (5x3¼ in.), irregular, and white to yellow from Chili also exhibits this mineral in its amorphous waxen and sectile form perfectly with drusy crystalline walls. An occurrence of unusual flattened crystals (octahedrons) from Tombstone Arizona is one of characteristic interest.

There are a few very fine *Embolites* from the Broken Hill Mines, New South Wales, the manganese surface holding implanted cubo-octahedral crystals, rather well isolated and many distorted; also a noticeable specimen from Chili! Cubical Bromyrite from Mexico, *twinned* and single crystals of *Iodyrite* from New South Wales, of superior excellence, and an interesting association of descloizite, vanadinite, enargite(?) and iodyrite succeed.

A **Penfieldite** of unrivaled beauty is near at hand, the cluster of white prisms radiating starlike in a shallow dish of lead slag from Laurium, Greece. The iodide of copper (*Marshite*) is repre-

sented by just one specimen of great beauty—the tetrahedrons being perfectly developed. It is from New South Wales.

Fluorite has received Mr. Bement's very careful attention. The exhibit is beautiful. It is varied, it pleases the taste, and it satisfies all scientific demands. Of course to enumerate in detail the specimens of this fine assemblage is impossible, nor would it prove instructive. A helpful division of their consideration would be into the continental, the English, and American "fluors." In large collections the local habit is accentuated through a repetition of specimens, and becomes impressive. The beautiful rose-red octahedron of St. Gothard, the curiously pitted (tetrahexahedral) and channelled faces of green cubes from Brienz, the small purple Schlackenwald cubes, with chalcopyrite, the amber-yellow groups with galena from Saxony, the pale green or pink cubo-octahedrons from the Grimsel on smoky quartz, the white Phoenixville, Pa. cubes, the whitish-green octahedrons from Cornwall, the Rabenstein wonders, the rather insignificant development of modified cubes, with orthoclase, from Baveno, and the glorious line of Cumberland and Cornish crystals, with their charming colors and the frequent curious vicinal planes of scarcely raised tetrahexahedrons are all here. There is a wide range of color and the light-blues, violets, greens, purples and intergraded tones of color, form a veritable garden of mineral bloom. A striking specimen from Schwarzenberg, Saxony, of green octahedrons with purple tips; also octahedrons built up of cubes; very fine dark-purple cubes, with barite from Bavaria; blunted and rounded cubes, greenish white, with low tetrahexahedrons from the Austrian Tyrol; and a superb parallel crystallization of the four-faced cube from the same locality, as a second generation on quartz-covered cubes; hexoctahedral planes in specimens from Baden, Switzerland, Cornwall Cumberland; green octahedrons, cubo-octahedrons from various localities, with an especially alluring Grimsel group of white crystals with rose centers; exquisite groups and strayed crystals on smoky quartz from Switzerland; large pink octahedrons from St. Gothard; octahedrons built up of separate octahedrons from Göschenen-Alps; the pitted crystals of Brienz, Switzerland; a lilac octahedron from Elba, Italy with planes of the trigonal trisoctahedron; a cube octahedron and rhombic dodecahedron with quartz and pyrite from the island of Giglio Italy; are notable examples outside of the long English suite and the American specimens. The vagaries of the cube are well shown in the English specimens in flat and elongated and curved forms. There is a beautiful cube from Weardale with an underlying cube with octahedral faces; banded (in color) crys-

tals; tetrahexahedral vicinal faces and striae admirably shown; a fluorite with included bubbles; the hexoctahedron facets well marked; green octahedrons built up of cubes; cubes showing secondary growth with a different orientation; curious irregular eroded cubes; eroded green cubes with purple fringe on dentelate edges; fine Cornish tetrahexahedrons; rhombic dodecahedrons from Luxulyan; chlorophanes; central depression of cube faces; dark purple tetrahexahedrons; green-lilac octahedrons, Cornish, but exact locality not given; a rare example of cube faces roughened by innumerable minute cubes, Cornish; Devonshire fluors of amazing beauty in color, one showing a, o, d.

The American fluorites, as is too well known, except in New Hampshire, offer no comparison to the foreign specimens; they are poor, bleached and generally small. The St. Lawrence Co. (New York) find was exceptionable. Mr. Bement has green cubes on talc from the Tilly Foster mine, N. Y., also white and dark purple and canary-yellow, from the same locality. A remarkable combination of the cube, rhombic dodecahedron, and tetragonal trisoctahedron from Phoenixville, Pa. is worthy of note. Yellow cubes from near St. Louis, Mo., the dark purple-red cubes from Shawneetown, Illinois, with specimens from Lake Superior, Colorado, New Mexico, Arizona close the series.

Sellaite is represented in crystals on anhydrite from Piedmont, Italy.

Cryolite from Greenland, is splendidly illustrated in two specimens, both consisting of superb prisms, with crystallization extending over entire surface (3098, 3102) rising from massive cryolite, with siderite. *Chiolite* with very fine *Thomsenolite* in beautiful crystals; crowded acute pyramids of *Pachnolite;* magnificent small and broad crystals, with terminal planes, of Thomsenolite (3178); flossy netted crystals of *Gearksutite;* octahedral *Ralstonite;* (3183, 3184) are excellent features.

The **Matlockite** is of high quality, No. 3107 is a large rosette of tabular crystals, in a pocket in galena, and its companions, all from Derbyshire, present intersecting plates and crystals with dome and pyramidal faces.

Laurionite is very beautifully shown in slag cavities, *Percylite* in blue to green crystals through rock; *Cumengite* in trillings, very large and striking; **Atacamite** from Australia receives a superb illustration in dark-green large crystals projecting in group from the parent rock, another from Australia shows prisms and terminations. In the rich acicular encrustations from Chili its more familiar appearance is presented. The white seedlike crystals of

Fluellite thickly sprinkled on a surface of granite are interesting and unusual. *Prosopite* occurs as imbedded crystals in decomposed granite with Cassiterite, also in white flesh-colored crystals in massive hematite, both from Altenberg, Saxony.

The **Boleite** forms a grand termination to this section and in No. 3202 reaches a really spectacular climax. This specimen exhibits a number of scattered cubes in the matrix, the largest of which measures 9-16 of an inch (1.44 c m) on the edge.

There are fourteen entries under this species, and in one, at least, twelve separate crystals are included. The tetragonal symmetry is shown. Species 45—Specimens 527.

THE OXIDES.

The oxides do not generally offer difficulties to the collector. Most of them are not unusual or expensive minerals, and only in a few instances do they reach that degree of rarity which limits their possession to the rich collectors. And they are not difficult minerals in another sense. Their identification, with some exception, is easy and conclusive. Yet in this section by reason of the great value of very superior specimens, and the gem character of at least five of the species, a delicate regard for one's pocket book will not promote the distinction of a cabinet. Perhaps more money can be expended on the oxides than in any other section, though it is just as certain that representative collections, expressive and attractive, can be assembled at a reasonable outlay. Here we encounter Quartz, as Prof. Miers notes, "not only the most common, but, *from every point of view,* one of the most interesting of minerals," Corundum with its gem forms, Cassiterite with its twin crystals, the wonderfully twinned Rutiles, the exquisite Anatase (Octahedrite), the crowded Hematite rosettes from Elba and St. Gothard, the, now, rare Spinel octahedrons from New York, the unique zincite, limited so strangely in its development to practically one locality in New Jersey, the beautiful *Antimony* oxides, and the marvellous acicular cuprite spread out in scarlet webs over quartz or limonite.

In the Bement Collection a very large series of superior **Quartzes** are shown, and amongst them the unusual crystals from North Carolina, which Von Rath described, and which Hidden found in Alexander Co. of that state, with the rare basal truncation and the most uncommon trapezohedral terminations, the di-hexagonal prism, and the steep rhombohedral planes and trigonal pyramid. There is a fine suite of the Butterfly twins from Miyamoto Mura,

Japan, showing the apposition in a right angle of the prisms and the gradual suppression of the prismatic faces until the rhombohedrons meet in a scarcely inflexed line.   Sometimes these are twisted, R, and -R, on the same aspect.   There are interesting crystals from P'oretta, Italy, hollow faced, with superimposed quartz films, very oblique crystals, the interiors feathered and filmed, and parallel growth of three crystals forming babel summits.   A beautiful pellucid crystal of quartz in Carrara marble has interest. Amongst singular examples of this protean species there is noticeable, a trigonally compressed prism from Rio, Elba, with R well developed and —R- in truncating planes, two delicately smoky crystals right and left handed, trapezohedral planes doubled, shown at each termination, the two reversed crystals opposite and separate, a superb doubly terminated crystal saturated with chlorite and sprinkled with hematite, and a bifid apex (3290) from Göschenen; a large beautiful group, with curved crystals, showing intergrowth, from Graubünden, Switz.; a curiously flattened and produced crystal, making a knife edge at each end, slightly smoky from Guttenen Switz., (3300); fused group of crystals, doubly terminated, slightly smoky, curved, trapezohedral plane broadly developed, from Maderanerthal, Switz.   There are numerous Swiss crystals pitted, eroded, flexed, and composite, that, though inexpensive, have been chosen with a nice eye for crystallographic peculiarities.   Interpenetration twins from St. Gothard, trapezohedral developments also that are unusual, and curious splinterlike crystals (3339), triangular with roughened surfaces, and many twisted specimens, with flattened crystals, etched and hollowed faces, others with streaked faces like a smearing over a plastic surface, again crystals penetrated with flat bladelike passages, the icelike crystals charged with byssolite, and associations of heulandite, amphibole, molybdenite, hematite, etc.   A free quartz crystal from St. Gothard is "ruptured" and each side of the break recrystallized.   The selection of smoky quartz is superior, and as is usual displays crystallographic rarities. Selva Switzerland furnishes some very handsome specimens, resembling the other smoky quartzes from its neighborhood, and there are remarkable groups from Tavetsch, (3404-3415), with wonderful inclusions.

There is a delightful assemblage of amethysts, the dainty capped ones on pedestals from Chamounix, the turretted groups from Hungary, fine ones from Transylvania, and those from Zillerthal, with many beauties, apparently selected from the Spang cabinet.
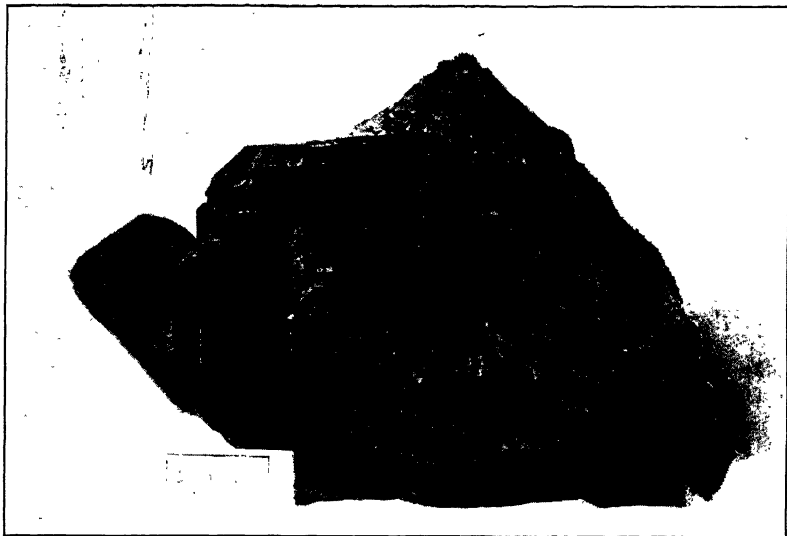
COLUMBITE
Haddam, Conn.
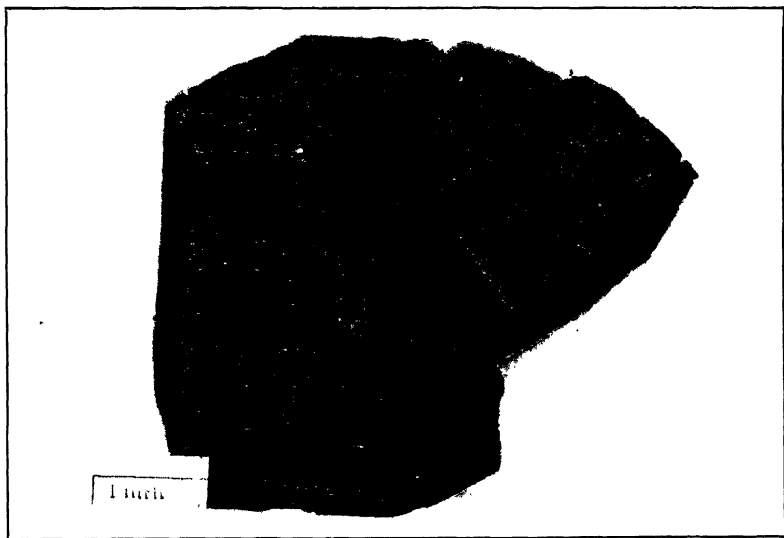
PHLOGOPITE
S. Burgess, Ontario, Canada

Schemnitz, Hungary, shows the association of sphalerite, drusy quartz encrusting barite, amethysts on calcite, while from Felsobanya comes a singular group of white crystals sprouting from a flat hollow blade, illustrating the rapid and eccentric power of crystallization in this inexhaustible species. There are some superb examples from Auvergne, France, many from Dauphiny, a series of English quartzes, many of great interest, and many of high cabinet beauty. There is an interesting clear crystal on a partially developed prismatic pediment, with oblique, striated, wavy and undercut faces, from Carlow, Ireland. The amethysts from Hungary, the crystals from Brazil, many of them singular, with basal plane, with zonal coloring, and many peculiarities; with a long series from Guanajuato, Mexico, characterized by delicacy of coloring!

The Thunder Bay amethysts, the flattened blades from Haddam, Conn., with a curious truncated stout crystal, and a modified crystal with possibly new faces, oblique clouded and curved faces from Ellenville, N. Y., the Herkimer groups, with bubble cavities, strongly colored amethysts from Upper Providence, Delaware Co., Pa., and from Chester, Pa., with smoky quartz, and numerous other localities, form a part of the large American suite!

The Alexander Co., N. C., specimens are *sui generis;* they form a remarkable group. The North Carolina quartzes number one hundred and twenty five, including Lincoln, Macon, Catawba, Iredell, Burke, Buncombe counties. The Arkansas groups and crystals are varied and very superior in quality; the sharp edges, clean apices, with phantoms, etched faces, with cruciform and interfering effects are conspicuous. There are a great number of interesting Colorado specimens, and many very beautiful, as might be expected; amongst these a ferruginous, dense, opaque pitted crystal broken with recrystallized surfaces. Wyoming, Montana, New Mexico, and Arizona are represented.

There is a superb doubly terminated crystal from California with phantom with snowy terminal faces. There are pseudomorphous conditions after Barite, Calcite, Crocidolite, Fluorite, Glauberite, Gypsum, Prehnite, Pyroxene, Scolecite, Stibnite, Spodumene, Siderite, Thenardite, Wulfenite, numerous excellent chalcedonies, and the usual influx of agates, chrysoprase, carnelian, onyx, etc. No reference has here been made to the wall case specimens many of which, as the enormous smoky quartz crystal—The President— from Switzerland, are notable.

The *Tridymite* comes from the Ural Mountains, Padua, Italy, Mt. Agnone, Italy, Pachucha, Mexico. There is excellent *Melano-*

phlogite from Sicily, and varied and beautiful **Opal** from New South Wales, Barcoo River Australia, Chili, Hungary, Giesen Germany, Saxony, Silesia, Honduras, Mexico, Colorado, Idaho, Washington, with the varieties of *Forcherite, Cacholong, Jasper-opal, Praseopal, Wood, Alumocalcite, Quincite* (?) *Geyserite, Fiorite,* *Menilite, Hydrophane, Hyalite.*

There are splendid octahedral specimens of **Senarmontite** from Algiers, some crystals one-half an inch in diameter, and a specimen from Sardinia and one from Canada. The Pribram **Valentinite** is superior. There is a remarkable *Cervantite* from Borneo, consisting of yellowish-white hollow crystals, in a broad group.

In **Cuprite** the Bement specimens are very excellent, and the section where this satisfactory mineral with its definite and regular crystallization is displayed, with beautiful examples of *chalcotrichite,* is very conspicuous. The Cornwall groups are strong and brilliant; many large crystals, the rhombic dodecahedrons also common; and heaped up crystals in sumptuously rich specimens, while in one specimen the cube, octahedron with rhombic dodecahedron are implanted in the midst of green spheres of *Andrewsite* on a limonitic base. The whole suite is admirable. The Arizona specimens are fine and sometimes give a patriot a pardonable thrill of pride in their flattering comparison with their famous English competitors. Among these (4560) is a lovely group of purple-red cubes on native copper, and a stalactite (4567) of malachite coated with azurite, and very regularly sprinkled with cuprite octahedrons. Some skeleton crystals from Boleo, Lower California deserve mention, they are hollow faced octahedrons with *d* planes. No. 4583 is a group of cubes elongated and regular, covered with malachite on a cupriferous limonite gangue. The *Chalcotrichite* comes from Tennessee Michigan, Arizona and Germany.

A blue-gray octahedral *Periclase* in an ejected nodular limestone from Monte Somma, Italy follows.

There are eleven **Zincite** specimens, with the exception of two artificial specimens, all from Sussex Co., New Jersey. These, one suspects, have been carefully selected and of course the crystallized examples are very precious. There is a zincite enclosed in calcite, in long cylindrical stringers, one bag-shaped mass with peculiar pressed surfaces. There are four crystallized specimens, of these the largest possesses six well-defined crystals, one of considerable size, implanted on a mixture of franklinite and zincite.

The **Tenorite** is from Vesuvius, Michigan, and Arizona; two handsome specimens of *Paramelaconite,* one showing tetragonal
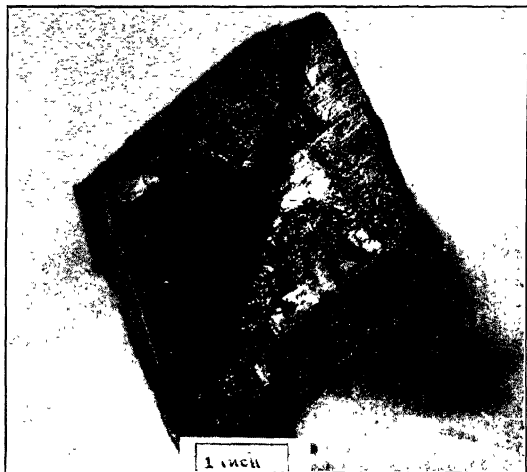
TITANITE (Twinned)
Renfrew Co., Canada
Bement Collection, American Museum of Natural History

APATITE
Bob Lake, Ontario, Canada
Bement Collection, American Museum of Natural History

prisms, with pyramid and basal plane, upon a crust of crossing and erect crystals, the second is a large crystal in a small group, over cuprite with blue *Footeite* and both come from Bisbee, Arizona.

The **Corundum** is abundantly illustrated, with many of beautiful color, and many well crystallized; among a great number some distinction may be given to a ruby prism and pyramid in dolomite, base meshed with cross striations from Switzerland; prism and pyramid in matrix from Franklin, New Jersey; Gray-white to blue-gray groups from Delaware Co., Pa. (many of these seem referable to Mr. Joseph Wilcox); splendid specimens, from the Joseph Wilcox collection, from North Carolina, with most interesting examples of the characteristic superficial and penetrating alterations; a superb compressed crystal with ripidolite from Franklin, Macon Co., N. C., and some other handsome specimens from this famous locality, showing cross sections, with the striations, and varied colorings; here occurs a splendid distorted crystal, very blue, translucent cavernous and without matrix. There is a crystal, with blue center, red exterior from Pine Mt., Rabun Co., Ga., and a number from Chester Co., Pa. which suggest the enriching labors of Mr. Jefferis. The Corundum section is again a section which Mr. Bement has polished by review, selection, and separation.

Hematite is not a very attractive species, except under the best auspices which Nature can summon to produce it. In ordinary examples, devoid of delicate or enticing colors it fails to please; and only in brilliant surfaces or in the wonderfully aggregated crystals of Switzerland and Elba does it attain such excellence as to place it in the higher class of mineral marvels.

The Bement series begins with some interesting crystals from Ascension Island, in single compressed oblique and distorted rhombohedrons, with oscillatory striae; and naturally allied to these are the wonderful thin plates made up of overlapping films from Madeira. There are beautiful crystallizations from Vesuvius, some of which are labeled "eruption of 1872." The Swiss examples are certainly superb, and many of them came from the great Spang cabinet; the crystallization and groupings are admirable in scientific perfection and aesthetic arrangement; splendent plates built up on quartz with adularia and rutile, one thick plate showing rhombohedron and pyramid (of the 2nd order), and large composite crystals amazingly handsome, with "rose" forms exquisitely illustrated.

The Elba specimens are only less remarkable. The crystals are dense, heavy, iridescent, showing rhombohedron and 2nd order pyramid in single crystals of the clearest definition; with twinning, and confused and swedged bases, blistered and tarnished sur-

faces, creased and channelled; stout crystals cracked by earth movement, an elegant assemblage. The Dognacska compound or twinned crystals are interesting, also those from Langban, Sweden, with striated basal plane, with richterite. There is an odd spherical specimen from Cumberland, England, made up of quartz aggregates in plates with the edges of the plates fringed with black hematite crystals.

The **Ilmenite** (*Menaccanite*) is in good crystals, a few of huge size with the varieties *Washingtonite, Kibdclophane, Paracolumbite, Hystatite, Crichtonite* represented.

Spinel is a monotonous species, its restricted habit affording very narrow limits of variation, and its coloring not very greatly relieving its meagre interest, though hemitropism and the pleasant rivalry of collectors to get big octahedrons, has made it a species of some fame. Mr. Bement has fine Ceylonnese crystals in green and blue and pink, black octahedrons with *fassaite* from Fassa, Tyrol, with *chrysolite* from Vesuvius, rare striated cubes from Wakefield Canada, admirable crystals (m and o) from Warwick, Orange Co., N. Y., and the enormous crystal from the same locality, in part altered to a steatitic substance, with other localities well represented. Spinels from Franklin, Sterling Hill, and Sparta, New Jersey, are valued, and the collection affords some seventeen specimens. The *Gahnite* on Rhodonite forming very lively groups, is from Franklin Furnace, New Jersey; the gahnite from Sterling Hills, New Jersey is fully represented.

Magnetite presents few or no surprises, sharp lustrous crystals, (one showing hexoctahedron from Russia), combinations of o, d, m, interesting associations, hemitropes, pseudomorphs, striated faces, the cleavage blocks from Essex Co., N. Y., remarkable rhombic dodecahedral crystals from Berks Co., Pa. constitute its features.

Before reaching **Franklinite,** there occurs an immense octahedron of Magnesioferrite, from Mt. Somma, Italy, cut with the clustered rhombohedral plates of hematite. Passing Franklinite and *Chromite* the visitor finds some excellent **Chrysoberyl** crystals from Ceylon, Minas Geraes, Brazil, twinned plates in granite from Greenwood, Me., and one large twinned crystal from Saratoga, N. ,Y. The **Braunite** is not extended, as it has no reason to be, but two crystals, one from Langban, Sweden, and one from Piedmont are deserving of mention.

Tetragonal minerals are not provided by Nature with as many crystallographic idiosyncrasies as others, except as she can inject confusion and variety by twinning, and this she does in Cassiterite

and Rutile with amazing skill. Mr. Bement furnishes for inspection two very handsome, in Rutile almost unique, selections in these two species. The **Cassiterites** amongst American collections rank high. Here are beautiful specimens from Schlackenwald, Bohemia, single and multiple twins, gathered up in pyramidal piles, or enclosed in matrix rock, splendid crystals from Zinnwald, Bohemia, from Saxony, with topaz and fluorite, the stout Morbihan prisms and pyramids, large Spanish crystals, single crystals from Portugal, the "sparable tin" from Cornwall, with other old specimens, simple short crystals, and a singular substitution of cassiterite for quartz, reputed to be unique. The specimens of Cornish tin-stone and crystals are unrivalled in the British Museum, and of course no comparison in this locality should be made between them and the Bement specimens. There is one striking specimen of translucent red crystals from Elsinore, New South Wales, and a cinnabar-red specimen from Durango, Mexico. Amongst American localities, Virginia, S. Dakota, Maine, occur.

Rutile makes one of the stopping places in the mineralogist's inspection of this great collection. Here are assembled a notable crowd of fine crystals and groups that seem almost to emulate one another in calling for attention, and in the Graves Mt. Ga. locality are not excelled in the world.

The Tavetsch, Switzerland specimens are quite numerous and attractive, there is a closed geniculation in adularia from St. Gothard, fine "elbows" from Binnenthal, intersecting twinned groups from the Tyrol, a Piedmont compound geniculation, Norwegian crystals, superior Styria crystals, prisms of two orders, and 1st and 2nd pyramids.

The American examples begin with heavy, thick, twinned crystals from Clay Co., N. C., a splendid channelled group, doubly terminated from Mr. Hidden; others very long (4 in.) from Alexander Co. N. C., also from Hidden, and others equally interesting, with rutilated quartz, many with perfect terminations, and emergent from dolomite, especially valuable ones from Stony Point. In the Graves Mt., Lincoln Co., Ga., specimens, so famous and justly prized, Mr Bement has been most lavish in his expenditure. They make up a group of sixty-five specimens of the highest grade of excellence, and they have been culled from some of the first and best collections made at this classic spot under good auspices. 5551 is a glorious group with zigzag summits, 5552 two large intersecting crystals, 5553 a large crystal, oblique, interrupted apex, 5555 multiple twin, 5558 a single doubly terminated crystal surprisingly good, 5562 a sixling distorted, 5569 a superb twinned

Fine **Manganite** from Ilfeld Harz, one especially magnificent specimen bought from Hoseus, are noticeable, and also the crystals sprinkling the surfaces, mammillated and stalactitic of göthite on limonite from Negaunee Michigan, with others.

Amongst the **Limonite** may be mentioned long iridescent pipe stalactites on a crustlike floor from Rossbach; altered pyrite from Elba and Pelican Point Utah, and pseudomorphs of enormous size after Siderite from Catawba Co. N. Y.

Brucite is an American mineral, at least the crystal groups and chains, spheres, and plates from Brewster's N. Y. and Texas, Lancaster Co., Pa. are unrivalled. There are twenty seven brucites in the Bement collection, and a few as 6095, 6108, 6109, 6110, are probably unequalled. Species 73. Specimens 1931.

THE CARBONATES.

The Carbonates form a small section in the mineralogical series and lacking hardness and density fall behind other minerals in their gem availability, though in marbles, in azurite and the "Mexican onyx" ornamental material of wide usefulness is found. Again their perishable and vulnerable constitution, yielding to the disintegrating action of acids degrades their position as "stones," although it subserves common industrial needs. In a mineralogical point of view they furnish beautiful specimens, in color and combinations, and in Calcite attain crystallographic profusion. To make a collection of Calcite which will possess distinction, and not be a monotonous repetition of similar or identical forms, a collection which will include also the widest diversity of occurrence, and portray the conspicuous elements of delicacy and variation so noticeable in Calcite—to make such a collection demands memory, scientific or technical insight, and indefatigable comparison. The group of Calcites in Mr. Bement's collection is, in this respect, one is tempted to say, of unique eminence. The impression made by its examination is a little startling, because of the exquisite care shown throughout, the absence of ordinary specimens, and the very elegant expression of the group as a whole, its dignity and beauty.

The Calcites are naturally divided into the foreign specimens, including the English and the superb suites of Guanajuato calcites, those from Lake Superior with copper, and the Joplin crystals. Throughout these are unusual combinations and very many possible novelties. The Guanajuato series abounds in admirable study groups. Here are remarkably large scalenohedrons grouped on quartz (6632) with the alternate and lower edges replaced by an amethystine crust; here exquisite groups of butterfly twins (6642), curiously distorted scalenohedron (6645) on quartz; a flat pris-

matic crystal that resembles a tremolite blade (6647) ; flattened and produced rhombohedrons, crystals between plates of quartz (6660) ; truncate rhombohedral cakes—pitted and jutting with parasitic rhombohedrons on quartz (6663) ; a remarkable scalenohedral twin forming two rhomboidal blocks; suture line distinguishable in oblique line through centers.   The truncated crystals are frequent, the association with amethyst common, distortion and compression occurs, pellucid ruled rhombohedrons, butterfly twins, and ideal crystal combinations of the rhombohedron and scalenohedron are seen all over.   A unique twin (6687) appears like a long prism—· seven inches—which divided by cleavage reveals its rhombohedral reference.   The 6693 is an illustrative scalenohedral twin, and 6697 curiously flattened plates, while in 6707 by the interpenetration of V on two crystals analcitelike individuals seem to be produced. No. 6731 is a mineralogical oddity, a scalenohedron—spurred on alternate edges above and below with secondary scalenohedrons. There are many examples of piled up—saucer-style—plates with scalenohedral edges and summits roughened with rhombohedrons; 6747 is elongated V and R faces produced into white glassy prisms; from 6752 to 6764 is a series of most interesting crystal showing wonderfully striking combinations of V- and R- with twin forms. There are indeed too many "points of interest" to specify in a running inspection and purely reportorial notice, as this is, among these Guanajuato specimens.

The Lake Superior crystals have been made known in large measure by the work of Prof. Palache, and cover the card catalogue from No. 6837 to No. 6892.   They possess splendid quality and may challenge the supremacy of the Houghton School of Mines specimens.   Nos. 6847, 6848, 6851, 6852, 6854, 6860, 6863, 6867, 6870, 6871, 6872, 6875, 6876, 6877, 6878, 6881, 6884, 6885, 6889—the latter, a hundred dollar prize, consists of an immense transparent crystal, holding copper, and exteriorly roughened with implanted crystals; form V and R, with distortion and apparent intergrowth; one side enclosing small green mass of quartz crystals—are preeminent.

The Joplin calcites are of exceptional beauty, and the exquisite terminations in perfect preservation and lustrously clean and brilliant, while the delicate tints range from honey-yellows to pale amethystine shades.   As Mr. Headden has observed the yellow calcites of Joplin are phosphorescent and the yellow portions of the crystal are superficial, belonging to the last stages of crystalline growth.   The depth of color grades into muddy browns, but in numerous examples, the yellows shade into delicate violets in the in-

terior or at the base of the extremities. The series is of high quality with notable individuals. A curious crystal made up of the rhombohedron and scalenohedron with waving edges of the R. faces (6931), distorted interpenetrating twins (6932), and remarkable twins (6933, 6954), with interesting associations (6934), chalcopyrite inclusions (6937), compressed shortened combinations of R and V. (6944), distortion and superficial erosion (6946, 6949, 6951), trapezohedral faces (6948, 6963), are a few features selected almost at random.

I have instanced only a few of the numerous interesting features of a very attractive group. The examples from New Mexico, Bergen Hill, N. J., Antwerp, N. Y., Rossie, N. Y., with numerous unusual phases from European localities are most noticeable.

Dolomite, a more monotonous mineral than calcite is presented in few specimens among which those from Alexander Co. N. C., the Swiss forms (twins), with remarkable crystals from Guanajuato Mexico claim preeminence.

Siderite is handsomely displayed. The specimens are quite numerous and remarkably varied. The mineral, except as it is illustrated by differently inclined rhombohedrons, basal planes, and the scalenohedron, claims no especial interest, and in color maintains a dull uniformity. Nos. 8083, 8088, 8089, 8093, 8094, 8099, 8106, 8127, 8137, 8144, 8143—this a rhombohedron with secondary faces on quartz—8144—a striking specimen made up of a steep rhombohedron and base—8149, 8156—steep R, base, and zonal succession of pale and dark areas—8159, with many more Cornwall examples are conspicuous in the foreign localities. From Pinal Co. Arizona appears a much curved compound R in groups, made up of smaller units, and with a varnished reddish-brown surface.

Rhodochrosite is a sort of flower among minerals, and in the beautiful alternations of its colors, and their enhancement by contrasted associations that act as a foil to its beauty rests its peculiar prominence in cabinets. The mammillated surfaces from Hungary, Germany, etc., are very pretty, the rhombohedrons and base also very good, with an unusual (8238) specimen showing V, and crystallizing over pyrolusite; there are some yellow crystals—V—with curious red pustulate spheres from Nassau, Germany, and translucent crystals; delicate pink crystals surmounted by calcite from Freiberg, small groups of pink disks of curved rhombohedrons forming cushions, and very effective, from Transylvania, pink rhombohedrons on edge as intersecting curved films with erect quartz crystals, from Schemnitz, and very beautiful examples from Siegen, Germany, Kapnik, Hungary, and then the glorious American speci-

mens from Colorado, among which occurs No. 8260, countersigned by Dr. Kunz, as the "King of all the Rhodas," though to our thinking 8272 easily surpasses it.

The **Smithsonites** (Nos. 1893-8365) are less interesting than associated species, but present, in the usual way, a feast of colors, especially from Laurium, with crystallized examples from Altenberg, Saxony, Aix-la-Chapelle, France, Broken Hill Mines, N. S. W.; and pseudomorphs from Mineral Point, Wisconsin. The *Sphaerocobaltite* from Boleo, L. Cal. is superior, forming pink to red encrustations on Atacamite.

The **Aragonite** (6560-8482) is represented by a series of the beautiful compound prisms from Cianciana, Sicily, glassy and of the finest quality, embellished by the showy association with sulphur (most of these date from 1892). No. 8384 consists of hollow columns, a rather odd example, and near it are handsome replacements of aragonite by calcite from Girgenti, Sicily, and compound twinned crystals from Herrengrund Hungary, while excellent transparent crystals from Bilin Bohemia show the terminations—pyramid and dome—and prism and pinacoid. The Spanish specimens are familiar, the very elegant surfaces of white needles on brown spath and calcite, with pyramids and dome from Cumberland England are less frequent.

Bromlite is represented by three specimens from Alston, England, in hexahedral pyramids on calcite and witherite. The Witherite itself is exceptionally good, of the usual types. Strontianite from Westphalia is present in crowded blades, upper surface crystallized with perfect summits, exquisite crystals from Hanover, and a greenish acicular group from Argyllshire Scotland of much beauty.

The **Cerussite** is a point of extreme interest and engages the attention of the accomplished collector. The specimens are of a high order, and less ordinary in their scientific character, than the preceding species. There are beautiful hexahedral pyramids on quartz from Baden, multiple twinning on galena from Bohemia, large twinned crystals from Mies, intersecting plates in spear-shaped groups from Ems, Germany, distorted produced crystals emergent over slaggy limonite from Cartagena Spain, splendid sardinian specimens in radiating and intersecting aggregates, a very large single crystal from the Urals, grand specimens from Tasmania and New South Wales, associated with the Anglesite from Broken Hills, and a long retinue of twinned examples of great value. Among American cerussites none exceed in beauty No. 8619 from Yuma Co. Arizona.

Barytocalcite in excellent specimens from Cumberland, England, follows, Bismutosphaerite from Saxony, and then Parisite. The fluocarbonate of the Cerium minerals is shown from Greenland, Montana, and in one (8644) superb hexagonal pyramid, erect in calcite, from Muso Valley, New Granada. The **Bastnaesite** is unusual; in the great fragments from Colorado, the perfect prisms, and the tabular portions with *tysonite* it is distinguished by very expensive and striking examples.

Phosgenite is another cherished species which has a limited development in localities and offers crystallographic interest, though simple in habit. The specimens of course are the English and Sardinian ones and reach a high standard. Nos. 8665, 8666, 8667, 8670 (ditetragonal faces) 8671, 8673, 8675, 8679, are preeminent.

The **Malachite** and **Azurite** quickly follow and make a striking exhibit. Africa, Australia begin the series with hard amorphous stalactites; then Betzdorf, Metzlar, Wissek, Schapbach, Schemnitz, from Germany follow, with Chessy (altered cuprites) France, handsome concretions and fibrous masses from Siberia, wherein many specimens are attributed to Dr. Leidy, succeeding. American localities embrace Berks Co. Pa., Ducktown, Penn., Greensboro, N. C., Pilot Knob, Mo., Utah, and the Arizona wonders. Among these note 8735, 8736, 8738, 8741, 8743, 8746 (pseudomorph after azurite), 8748, 8751, 8753, 8760. Azurite is more extended, and contains a fine set of old Chessy groups; witness 8773, 8776, 8777, 8778, 8781, 8782, 8787, 8793, 8795. There are superior specimens from Siberia, N. S. Wales (Broken Hills mines); 8818, and following numbers are worthy of remark; with the dazzling groups from Arizona in a long splendid section. *Atlasite* from La Costadera, Chili, in amorphous radiating patches; *Aurichalcite* in delicate plumose surfaces from New Mexico, Banat, Spain, Greece, Scotland, Arizona; *Hydrozincite;* (good from Argentine Republic); *Hydrocerussite; Dawsonite,* from Tuscany and Canada; *Hovite; Thermonatrite; Natron, Gay-Lussite, Lanthanite,* from Bastnäs Sweden, and a remarkably beautiful specimen from the Saucon Valley, Pa.; *Trona, Hydromagnesite* (the finest from Hoboken); *Lansfordite,* superficially altered to *Nesquihonite; Hydrodolomite, Zaratite, Remingtonite,* (rosy-red from Lower California), *Tengerite,* (globular on gadolinite) *Bismutite, Uranothallite, Liebigite,* (8975 crystallized), *Voglite, (schrockingerite), Randite,* complete the carbonates. Species 45. Specimens 1031.

THE SILICATES.

The silicates might quite generally be regarded as making up the force and beauty of a mineral collection, embracing too some

of the most widely distributed rock-making minerals. The phosphates, and arsenates, and sulphates might make also a claim to this regency but, all in all, no group or groups of minerals can fairly be said to rival the splendor variety and beautiful development of the silicates. Mr. Bement laid upon them some emphasis.

Petalite is shown in crystals (8980, 8981) from Elba: *Milarite,* in perfect crystals from Switzerland, white and greenish (note 8987); *Eudidymite* from the Langesund fiord Norway in lozenge-shaped twinned crystals, (8996 very good, also 8998); **Orthoclase** naturally shows up strong. The Baveno display is excellent (9003, 9007, 9009, 9018, 9025, 9032, are noticeable); the Mt. Somma series has interest, glassy plates of *sanidine;* Elba is represented with its white crystals accompanied with tourmaline lepidolite, quartz, Carlsbad and manebach twins; St. Gothard adularia has many noble examples (9062, 9063, 9066, 9072, 9075) Tavetsch, (9095, three separate manebachs in a field of quartz), Dissentis (9103, 9105) Gaveradi, (9108), Graubunden, Ruaras, Zillerthal, Grimsel, all contribute. Bohemia, with many specimens evidently referable to Norman Spang, Bavaria, Hungary follow with typical sets. 9137 from Germany is a fine trilling. Nos. 9154, 9159, 9165, 9166, 9181, 9182, 9183, are interesting or beautiful. The Canadian specimens are not remarkable. 9198 from Guanajuato Mexico is *valencianite* and is very fine, as also 9199, a similar specimen. The New York orthoclase is typical. 9231 is two interlocked green crystals from Franklin Furnace, N. J. from E. P. Hancock. There are some oddities from Leiperville, Pa., and some Amelia Court House beauties; then the Magnet Cove pseudomorphs after leucite; Michigan; Colorado, California, complete the list.

Microcline, separable from orthoclase by a scant difference of 30′ in angle, and by the grating structure or cross-hatching between crossed nicols, in thin sections, is handsomely represented by a noble suite of Colorado specimens (fine twin combinations) among which 9305, 9308, 9315, 9319, 9325, 9327, 9328, 9331, 9332, 9333, 9337, 9339, 9340, 9341, 9343, 9344, 9347, 9348, 9349, 9350, 9351 (from Wilcox Collection), 9359a, merit particular attention. *Hyalophane* in glassy transparent crystals from Binnenthal, is succeeded by the excellent series of **Albite.** Here are fine examples, of course, from St. Gothard, Oberwald, Tavetsch, Wallis, and other tyrolean localities, large crystals from Topsham Me., Haddam Conn.; a crystallized *peristerite* from Macomb N. Y. (9412), striking objects from Leiperville, Pa., Amelia Court House, Va., and twisted crystals from Magnet Cove, Arkansas.
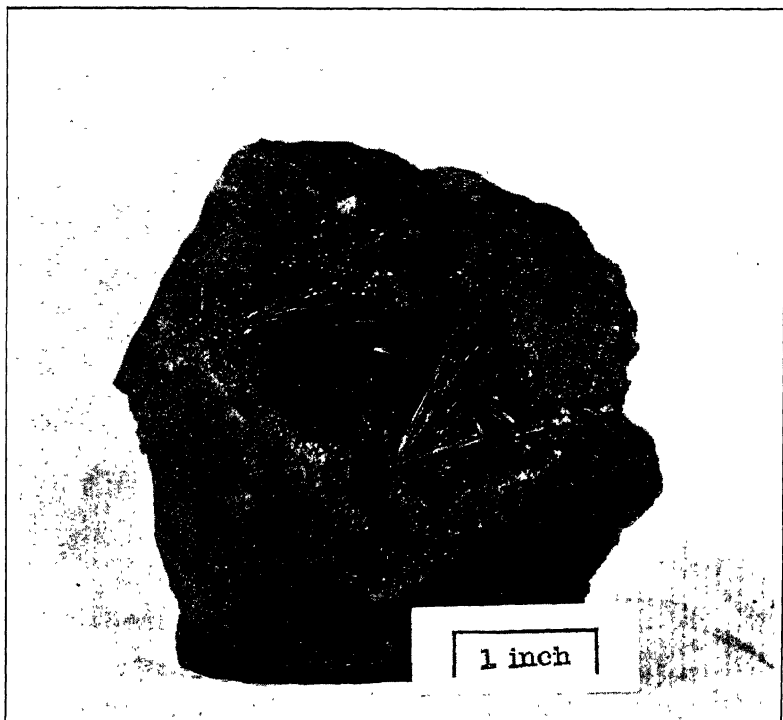
ERYTHRITE
Schneeberg, Saxony, Germany
Bement Collection, American Museum of Natural History
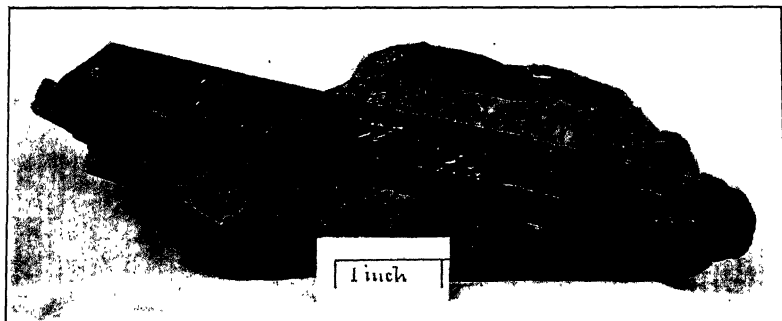
APATITE
Renfrew Co., Ontario, Canada
Bement Collection, American Museum of Natural History

Oligoclase in crystals, from Arendal, Norway; black crystals of Andesine in a matrix of pyrrhotite from Silberberg, Siberia, with "saccharite"; Labradorite (notice 9455, 9454); Anorthite from Mt. Somma, flesh colored crystals from Fassathal, Switz., from Japan, and the *doubtful* green specimens from Franklin Furnace, N. J.; Leucite, (9485, 9486, 9488, 9492); *Pollucite,* well shown crystallized in 9494 from Elba; Enstatite, from Bamle, Norway, with American localities, and *diaclasite* in crowded small bronzy crystals from the Hartz; *Hypersthene,* follow.

Pyroxene, is well developed, and remarkable specimens from Canada and northern New York have been taken from the Joseph Wilcox collection; these are particularly conspicuous. Handsome *diopsides* from Piedmont, *augite* from the Tyrol, from Piedmont (9539), from Nordmak, Sweden (9547, 9553), beautiful diopside from Val Maggia, Switz., (9576), good Ural sets (9580), *baikalite,* (9581), Bohemian and Hungarian crystals, Bavarian (9590), make an excellent foreign showing. Then follow the North American specimens, and numbers 9597, 9598, 9599, 9603, 9618, 9619, 9620, 9623, 9624, 9626, 9635, 9638, 9640, 9685, 9695, 9696, 9698, 9747 are most striking. Acmite, from Norway, in good crystals, from Magnet Cove (*Aegyrite*); Spodumene in handsome, stout crystals from Maine and especially in heavy channelled prisms, terminated, from Norwich, Mass., (9791 from Huntington, Mass), and superb *hiddenite (kunzite* was not known when the Bement collection left the hands of Mr. Bement) from Alexander Co., N. C. Nos. 9797, 9799, 9801, 9802 are exhibited. Wollastonite comes next with excellent white crystals from Mt. Somma, large crystals from northern New York, the problematic pink masses from Franklin Furnace, N. J., Pectolite with two superb terminated hemispheres of crystals. and a third, procured from Dr. Kunz in 1885, remarkably strong and perfect, and a specimen from Snake Hill, of radiating crystals on trap with interstitial chabazite, also one from Haverstraw Tunnel, N. Y., a *manganpectolite* from Magnet Cove, Arkansas, and massive pectolite from Tehama Co. Cal.; Rosenbushite, with *wöhlerite, låvenite, elaeolite* from Langesund fiord; Låvenite in yellowish white crystals from the same locality; Wöhlerite from Norway (note 9881); *Hiortdahlite,* from Langesund fiord; and then splendid Rhodonites, the largest of which, an unrivalled cluster of long prisms, is among the wall case specimens, follow. There are very brilliant Swedish specimens (Pajsberg) but the large crystals from Franklin Furnace challenge attention more exclusively. *Babingtonite* is in fine

splendent black crystals from Arendal, Norway, tabular from Baveno, and stout crystals from Athol, Mass.

Amphibole is a comprehensive species and Mr. Bement has brought together a good series of its illustrations, some of the hornblende groups (in wall case specimens also) being magnificent. *Richterite* from Långban, Sweden begins the series; the European specimens are not however so interesting, the Canadian and New York examples easily excel them in value, and these are very fine, Mr. Willcox supplying some important features. Note 10001, 10020,-27, 10042 (type) 10044,-46, 10053, also *jeffersonites* from Sterling Hill, N. J. See 10093, 10095, 10098, 10100, 10101. *Glaucophane,* Swiss and Italian, no examples of Californian schists; *Crocidolite* in blue fibres from Griqualand, S. Africa, with the silicified forms; *Arfvedsonite,* 10161, stout crystal from St. Peter's Dome, Col. (L. Cahn), *Pterolite; Aenigmatite* 10164 terminal planes with *eudialyte,* succeed. The **Beryl** is very beautiful. It is one of the places where Mr. Bement paused and deliberated, as it were, seeking and choosing the best. It is not so large a section but the material is effective. 10185 from Elba in pale blue crystals, 10186 pale rose in orthoclase, 10187 beautiful clear rose-red, pierced by tourmaline, 10188 exquisite termination, 10192 from Mourne Mts. Ireland, 10193, from same locality, also 10194 delicate sea-green, pyramidal planes, 10195, eroded, 10200 faintly rosy composite crystal from Urals, 10201 (sold by Hoseus to Mr. Bement as topaz) superbly finished, 10207 from Siberia light yellow, transparent, superb summit of pyramids, 10208-10213, 10222 interesting bisection of one crystal by another, curious, bright base, 10223 an extraordinary sea-green crystal, oblique pyramid, fretted or chiselled surface, 10226, 10227, 10229, 10245-50 Bogota emeralds, 10258, the great emerald crystal from Alexander Co. N. C., with brilliant base, tubular, color focussed on edges, divergent individuals, a famous piece, also 10260, 10269, 10296 a beryl enclosed in a larger crystal, some good opaque pink Haddam crystals, (surpassed by an included Bruce specimen), and the Maine short prisms with pyramid of the second order, are among the more striking spots in an admirable array.

Eudialyte, good crystals from Greenland, and the flattened ones from near Hot Springs, Ark.; a very fine crystal from Langesund fiord, Norway; *catapleiite,* 10365 in overlapping series of hexagonal plates, also 10372 are excellent; *melanocerite,* from Langesund fiord, *steenstrupine* finely shown in 10369; *tritomite; erdmannite; leucophanite,* 10378, perhaps twinned, 10379, is a superb small yellow-green crystal, twinned, both from Langesund fiord,

10383 with *astrophyllite* an unusually good crystal; *meliphanite,* crystal from Barkevik, Norway; **Iolite,** good crystals from Bodenmais, Hungary, 10395, *et seq.,* green from Bamle, Norway, 10407, 10408, mass crystals from Haddam Conn. 10416-10421; *barysilite; ganomalite; hyalotekite;* Nephelite, glassy white perfect crystals from Mt. Somma, *elaeolite* from Langesund fiord, crystallized; *kaliophilite* from Italy (Mt. Somma); *cancrinite,* 10462 crystals in matrix; *microsommite; davyne,* 10468, a mound of crystals on mica; *cavolinite,* crystals; *sodalite,* 10473 white crystals with idocrase, Mt. Somma, rhombic dodecahedrons in 10474, massive from Maine; *hauynite,* 10485 blue octahedrons with wollastonite from Mt. Somma, 10488 dodecahedral, 10489 white o; *noselite,* 10494 fine twin, hexagonal effect, with sanidine from Lk Laach, Germany; *ittnerite, (skolopsite); lapis-lazuli* 10518 a, o, d, from Persia; *helvite,* good from Kapnik, Hungary, Saxony, (10543); *danalite; eulytite,* 10534 splendent dark-brown crystals showing hemi-tetragonal trisoctahedrons; *zunyite* typical from Colorado, bring the inspection to garnet.

Garnet; this important species claims a collector's discriminating attention. It is common enough but good specimens can hardly be packed away *ad infinitum* in a collection, and the *infinitum* method was not Mr. Bement's. He has a splendid group of garnets; they are very beautiful and they are quite exhaustive. They begin with Dognacska specimens among which 10544, 10546, 10549, though cheap in price, are excellent, then Marawitza, Hungary, 10552,-55, Piedmont Italy in gemmy brilliant pieces follow. The Piedmont specimens are numerous. Zermatt, Switz., (10588, 10591, 10596, 10599), Elba, (10608, 10611), Frascati, Italy (10615), and Mt. Somma claim notice, among the latter 10617, 10621. A Salzburg, Austria, specimen, 10625, shows *a* faces (10625) well. 10631 is a white garnet from Silesia; here are good Fahlun examples and Arendal; Ural Mts. (10657, 10659, 10660) follow, the familiar Alaskan types, and some handsome individuals from Mr. Niven's Mexican quarries. The Canadian garnets are admirable, (10695-10705); the specimens from the States are perhaps the most attractive in the suite, especially the Maine, Connecticut, Massachusetts, (10765, 10764), New Jersey (Franklin Furnace), Pennsylvania (10794, 10795, 10797, 10799, 10805, 10808, 10809, 10810, 10816, 10820,), Tennessee (10842), Colorado groups and individuals.

Schorlomite, from Arkansas, Baden, and Finland; *agricolite; monticellite,* in good crystals from the Tyrol, from Mt. Albano, Italy, from Magnet Cove, Arkansas; *forsterite,* 10894 from Mt. Somma,

10896 colorless prisms and pyramids; **Chrysolite,** in crystals from Mt. Somma, the *peridot* in crystals from Asia Minor; *hortonolite,* 10923, good crystals from Monroe, N. Y.; *fayalite; knebelite; tephroite,* 10934 a crystal; *roepperite,* 10937 large chrysolitelike crystals with jeffersonite, also 10939; *trimerite,* 10941 red to yellow crystal on magnetite, bring us to willemite.

Willemite is conspicuously good, (the large troostite specimens in the wall cases are exceptionally fine), 10944-47 are striking, from Franklin Furnace, N. J., also 10951, 10953, 10955, 10957 (some prisms eight sided) from Sterling Hill, N. J., 10969-74, 10981; **Phenacite** furnishes handsome specimens, 10988 (from the Trautwein collection), 10989, from Sweden, a superb, large, distorted prism from Takowaja, Urals, 10991, and 10993, 10995 from Colorado; 10996, 10997, 10999, 11002, 11008, 11009, 11012, 11014, 11015, 11016, 11019, are Colorado examples of importance, 11023 is an immense lenticular fragment of a crystal from Whitman Cross, 11010 from the Ilmen Mts., Russia, is a beautiful lenticular crystal, free. **Dioptase,** 11025-28 from the Congo State, Africa, 11029-34 from Siberia are superior; South America and Arizona complete a fine series.

Friedelite from Pajsberg, Sweden; *pyrosmalite,* typical and large, from Sweden, 11045, 11046, 11047 are remarkably good; *meionite,* well crystallized from Mt. Somma; **Wernerite** (scapolite) is quite expanded, 11072, 11074, 11075, 11076, 11078, 11081, 11085, 11088, 11090 (cracked and mended by nature), 11098 embraces five pieces, one a Dana type, 11118; the suite closes with some *algerite; mizzonite* in glassy crystals in shallow cavity in Mt. Somma lava; *couseranite* from the Pyrenees; *marialite; sarcolite, melilite* (humboltilite); *gehlenite* 11231 gray cubical crystals; *cacoclasite* 11160 from Ottawa Co., Canada, bring the inspection to a brilliant display of vesuvianite and zircon.

Vesuvianite (idocrase) abounds in handsome specimens, the variation in color and the strong crystallization combine to give an agreeable characterization to this ancient species. The Vilui river specimens from Siberia in dark square prisms are good, the Mt. Somma ones typical, the Piedmont examples sometimes unusual, 11195, 11196, 11225, the Tyrolean sets varied, good Zermatt crystals are noticed and the Hungarian near them. Norway contributes 11219, 11220. The American examples from Sandford, Me., Canada, Montana, Arkansas, show some nice selections.

Zircon improved a good deal in cabinets since Canada and the United States helped out with their contributions. In the Bement collection 11255 from Siberia is a group of gemmy crystals

packed with black mica in feldspar, 11257 a steep pyramid from Miask, also 11263, 11264, 11267, all handsome, are from the Urals, 11277 is from Mt. Somma, a small gray crystal with nephelite, and 11278 is a companion, 11283 is a white doubly terminated prism from Pfitschthal, Tyrol; (see also 11285) the Azores furnish 11287, 11288; 11289 is a bright red opaque crystal from Prussia; the Ontario specimens begin at 11295 and extend to 11328 *et seq.;* note 11295, 11300, 11303, 11305, 11308, 11311, 11315, 11318, 11322, 11323, 11325, 11326, 11327, 11345, 11346, 11347, 11348. The North Carolina specimens are limited, Llano Co. Texas adds the familiar *cyrtolite* and Colorado closes the suite. A very good *alvite* 11424 is from Norway.

Then we meet **Thorite,** (Orangite), from Brevik, Norway, 11377, with pyroxene; 11378a, complete octahedral crystal from Langesund fiord, 11381-11382 red to brown-yellow square prisms from Arendal, 11388 a block of red prisms with pyramid, collected by Dr. Foote from Arendal; *auerlite* 11391, Hidden's specimens from Green River, N. C.; *eucrasite;* **Danburite** from Skopi, Switz. in splendid single and delicately terminated crystals; from the Grisons in an agglomerated crust of very small crystals, a Nordenskiold specimen (11399) from the Urals and then the Russel N. Y. revelations: note 11400, 11403, 11405, 11407, 11411, 11413.

Topaz is one of the spectacular spots in a rich collection, and there are many evidences of liberal expenditure among these fascinating groups. It would too much impair the balance of this sketch to dwell on all the fine things in this section; a few numbers only can be mentioned; the Saxony and Bohemian crystals are, many of them, beautiful, the Uralese very handsome, (11429, 11432, 11433, 11434, 11435, 11436, 11439, 11446, 11447, 11448, 11449, 11450, 11452, 11455, *11456,* 11457, 11458, 11460, 11463, 11464, 11465), the Japanese typical; some handsome Brazilian stones, and a good assortment of Colorado crystals (11500-11519) with Utah specimens of excellent quality and interest, and the elegant Mexican points complete a capital series.

Hessenbergite, one specimen, from St. Gothard, Switz.; **Andalusite,** 11568, dome faces on radiating crystals from Topsham, Me., 11574 long terminated crystal from Delaware Co., Pa., also 11575-78; *sillimanite, (bucholzite, wörthite, xenolite, bamlite, monroelite,)* ; **Cyanite,** typical from St. Gothard's, stout blue terminated prisms from Chironico, Switz.; **Datolite;** there is a long series of this species and the members of it are superior: the Tyrolean specimens are excellent (11629-11633), 11635 is a Hartz specimen with remarkably long prismatic crystals, *haytorite* from

Devonshire, the Norwegian *botryolite,* the U. S. groups with, of course, elegant Wiehawken (note 11663, 11664), Paterson (11670, 11676) Lk. Superior (11684, 11687, 11688) pieces, and concluding with a Tasmania surface of glassy white crystals with chalcopyrite and axinite, brings the order of silicates to euclase and homilite.

Homilite, a rare mineral, is represented by crystallized specimens from Langesund fiord, Norway; **Euclase,** in three not too remarkable crystals; *gadolinite* in capital Swedish crystals, (Ytterby) and Norwegian (Hitterö) also; there is a black crystal in fluoquartzose rock from Colorado, and then the Texan specimens (some of them types) from Hidden: *yttrialite,* from Texas; *zoisite,* in an excellent series (praised by Farrington) to which has been added the gray fascicled blades from the Juarez district L. California, (note 11728, 11733, 11734, 11735, 11737,), advances the review to epidote. ·

Epidote; the first glance at *epidote* reveals a handsome series of Piedmont specimens,· (11748-53,), and then the dazzling succession of Untersulzbach groups, (11768-777) (11783-88) (11805-09) with especial reference to 11809 (immense crystals), 11810, 11813; in all a splendid exhibit. 11831 is a solid sheet of parallel crystals from Graubunden, Switz.; 11834 a pseudomorph after *wernerite* from Renfrew Co., Canada.; the gray epidotes from Huntington, Mass., an oddity from Col. (determined by E. S. Dana) and 11866; the Ketchikan Alaskan developments had not yet attracted Mr. Bement. The suite is strong and representative.

Hancockite, (Mr. E. P. Hancock was Mr. Bement's assistant; he knew his collection exhaustively, and developed many specimens from sightless lumps of mineral, in which the imprisoned crystals were scarcely suspected) the multiple silicate of aluminum, iron, lead, strontium, and magnesium, is shown in two specimens, one of which, perhaps obtained before the identification was made, is labeled "what is this?"

The Scandinavian **Allanite** is characteristic and handsome, with good Ural specimens, (Bucklandite, 11888); *axinite,* is a "beauty spot" in collections though in a crystallographic way the mineral seems monotonous. The Swiss specimens are very beautiful, with admirable Dauphiny groups, (note 11938-39), and dark purple broad crystals from Tasmania, the Cornish specimens (11951) curious, and the Franklin Furnace ones, lit up with rhodonite, very effective.

Prehnite collections have been greatly enriched in the specimens of this species, by the beautiful examples from the New Jersey trap dikes. The Tyrol, Dauphiny France, Scotland, finds rep-

BARITE

Frizington, England

Bement Collection, American Museum of Natural History

BARITE

England
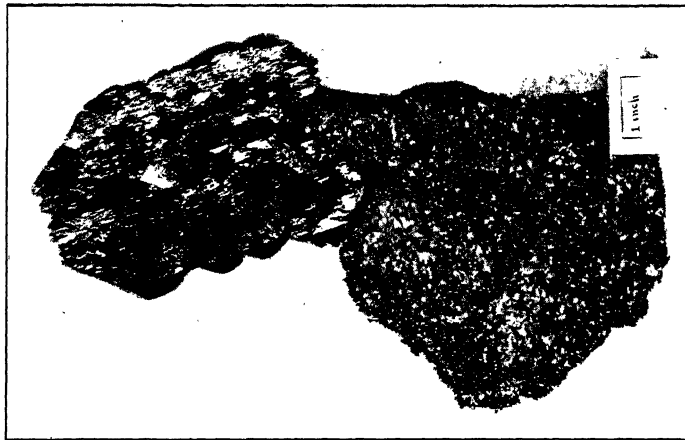
Bement Collection, American Museum of Natural History

resent it in collections previous to 1860, and since then the Bergen Hill, Paterson, gems have paled, by their splendor, their European rivals. Among the Bement specimens Nos. 11997-98-99-12000, 12003, 04, 05, are conspicuous. 12018 from Keweenaw Co. Mich. shows green combs of crystals enclosing copper grains. *Cuspidine* (2 spec), *Humite,* succeed, and then a handsome suite of *Chon-drodite,* which is astonishingly rich in specimens from the Tilly Foster mine, N. Y. There are excellent Swedish chondrodites but the Brewster crystals are superb (12037-80).

Ilvaite, the usual Elba crystals (now difficult to obtain) in fine examples (12096,-97,-99, 12100, 01, 03,-110); *ardennite,* orange crystals from Belgium; *langbanite,* black crystals from Sweden; *kentrolite, melanotekite* (massive), *bertrandite* in beautiful small crystals (note 12126) from France and Bohemia, with the Maine and Colorado (the latter associated with beryl and phenacite on quartz), *moresnetite, vanuxemite,* bring the series to Calamine.

Calamine; the excellence of calamine specimens is estimated, not so much by their mere beauty, as by the clearness of crystals showing its hemimorphic habit, and there are many of these in the Bement suite; (12139, 12141, 12142, 12153) while stalactitic, colored encrusting forms, meandriform convolutions, and pseudomorphs are abundant; *carpholite* in silken radiating tufts with fluorite from Bohemia, in veins from Belgium, in stellate groups of straw-colored needles, follows.

Tourmaline, this wonderful mineral with its play of colors and a rather precise and limited crystallization, albeit its apices offer some complexity, makes one of the signal series in any collection, and with a connoisseur of Mr. Bement's celebrity its excellence becomes a point of painstaking effort. Mr. Bement was enabled to secure some superior Elba groups and crystals. The well known charm of the delicate tinted tourmalines (like colored liqueur tubes) in association with orthoclase and quartz is well shown in these, some of which are mineral poems, (Nos. 12220, 12223,-24,-25,-36). No. 12239 is a splendid doubly terminated *rubellite,* deep-red in tone, and purchased originally by Dr. G. F. Kunz at the great fair at Ekaterinenburg, Siberia in 1887. A number of Siberian crystals (12236-266) follow, some like 12266, with a black nucleus and purple surface, of much perfection and beauty. The Bohemian and Swiss, Austrian, Hartz, Norwegian, English tourmalines are very good, but yield naturally in mere prettiness, to the Brazilian stones, one of which (12312) "purchased from a Junk-shop in Paris," is a cut and polished polygonal block of quartz, penetrated by tourmaline needles, while many are of gem intensity

and perfection. The Greenland specimens (12322-24) are strong black crystals, face development indifferent.

The Maine tourmalines are very interesting; they came from Kunz and Hidden (12326 with unusual terminal faces), and belong to some of the early and best finds; localities Auburn, Rumford, Stoneham, Hebron, Paris. The Mt. Mica crystals are not remarkable. Haddam Neck is well represented (12377, 12378, 12374, 12375, 12392, 12393, 12395, 12397, 12398, *et seq*) and the choice has been a collaboration of Bement, Schernikow and English. The northern New York specimens are very fine. I think many of them originated in the Spang collection, though Nims is a recurrent source, and also Willcox (12435, 12438, 12449, 12450,-51,-54). New Jersey specimens are representative though not as fine as the Canfield suites. The Californian discoveries hardly reached the acme of their development during Mr. Bement's period of active collecting, and these are insufficiently shown. The tourmaline specimens number 210.

Dumortierite, and *staurolite* rather "let down" the mineralogical excitement produced by tourmaline, though many specimens of the latter are capital; one (12534) showing an intergrowth of cyanite and staurolite is peculiar. The series from Cherokee Co. N. C. like the Fannin Co. Ga., specimens are typical.

Succeeding staurolite comes a rather singular group, the magnesium aluminum silicates in *kornerupine* and *sapphirine*. No. 12567 shows the gray needles of kornerupine like tentaculites, through the enclosing rock. *Barylite* in *hedyphane* (12571), *hypochlorite, monzonite, neociano, inesite* (the latter well shown, 12579-584), *okenite,* (from Faroe and Greenland), *gyrolite,* (12587, silvery, lamellar, in spherical surfaces on calcite), *ganophyllite* bring us to Apophyllite.

Apophyllite; this beautiful mineral, simple in form, through association and varying in color, or tint, from clear transparent glasses to the most softly shaded greens and pinks, attained a good deal of prominence in American cabinets after the revelation of the New Jersey traps. In the Bement Collection the Andreasburg (now rare) specimens are superior (12591, 12597,-98, 12603), a number of Swiss examples (12604 white crystals on pink octahedral fluorite), many from Iceland, (from Faroe ice-white encrustation upon fluorite, 12610), a good showing of the India large and imposing groups, the Michigan examples, (12643, tables implanted upon copper wire and with solid copper crystals, 12645 on analcite) are excellent. From New Jersey there is naturally an extensive exhibit, and while recent developments in the Erie cut have re-

vealed some superb specimens (Papké) it would be difficult to produce a finer array than the series here shown, (Note 12658, 12661, 12662, 12668, 12670, 12671, 12673, 12680, 12685, 12687, with chalcopyrite, 12689,-90); pyramids are rare or absent. Nova Scotia apophyllites are not numerous. Many of the Bergen Hill specimens come from Haines, an early collector. The Mexican (Guanajuato) series is especially fine, many of them very picturesque, and heightened in beauty by color and association ·(Note 12720,-28, 12731, 34). *Chalcomorphite, ptilolite,* (in white tufts of plumose fibres in cavities in an andesyte), *mordenite, xonotlite,* precede Heulandite, which is fully shown in series of beautiful specimens from the Tyrol, Switzerland, Scotland, Iceland, (these latter are handsome; note 12761-62, 63, 64, 12766,-67,-69,-771,-73, (grouped over ptilolite) 12775,-76), Nova Scotia, India, (12786), New Jersey (12789, 12791), (12798, *Beaumontite,*) Mexico. Then **Brewsterite** from Scotland; *epistilbite* (12809 geode of crystals, crowded, blue-white, "bought in 1884 from Dr. Hintze, for 250 marks, sold by him to be the best one found," 12812, 12815, 12818 from Bergen Hill in tufts of needles on prehnite(?)); *phillipsite,* (note 12824, 12821, 12831, 12834, 12838, fine specimens from Melbourne Australia); *harmotome* (12843,-45-46-47 from Scotland are characteristic; 12848-9, are from Ossining, N. Y., 12850-1, from the Harlem Tunnel, N. Y.); the *stilbite* specimens from Poonah, India, are exceptionally striking, (12852-863), the Iceland examples are frequently unusual, (12868, on Iceland spar, 12872); superb red crystal groups in calcite from Scotland, (12888); exquisite solid pearllike spheres of sphaerostilbite, nested upon acicular natrolite (12890), from Victoria; stout crystals, with argentite, from Chihuahua, Mexico (12894); spheres of large glassy crystals, forming dissepiment summits, (12899), very pretty; Nova Scotia groups (12897-911), a doubtful *sphaerostilbite* in milk-white smooth spheres enclosing chabazite, (12916), from Oregon, with New Jersey specimens make up a grand showing.

Foresite, (12956) is a minute encrustation on black tourmaline, from Elba; *gismondite* from Italy in white egglike sphaeres, with radial structure, concretionary, roughened surfaces of composition crystals, etc., is well shown (note 12939, 12941, 12942); *laumontite* is next (12951,-52,-57, 960, 965, leonhardite); after it *laubanite,* 12968 in gray spheres in amygdules, with a glassy drusy crystallization which may be, if not quartz, phillipsite, in trap; **Chabazite,** a monotonous mineral in habit though extremely effective in its associations, and interesting in its twins, and variety (*phacolite*) is generously exhibited from Bohemia, Silesia, Germany, Tyrol,

Sicily, Italy, Ireland, Nova Scotia, (*Acadialite*), (Note 13004), Australia (13006-13015) Oregon, New Jersey, (Note 13031), Maryland, Pennsylvania. In *gmelinite* the collection embraces 20 entries, among which, 13046, 13049, 13050, 13051, 13052 from Victoria, Australia are preeminent, 13055 is unusual, being an hexagonal prism, channelled from oscillation, with R- on datolite: *levynite* is shown in small crystals in amygdules (13063, 13065); **Analcite** in pink crystals from the Tyrol, in cubes from Switzerland, and from the Cyclopean Islands, in glassy crystals from Victoria, Australia, forms from Nova Scotia, perfect crystals from Michigan (13092-101); and the white surfaces from Bergen Hill (13114 is *Eudnophite*); *faujasite* (13116-118), *edingtonite*, (3 *superb crystals showing monoclinic symmetry No. 13121*) follow; **Natrolite** in a typical series, with especial emphasis on Nos. 13129,-130,-137,138,-139, 13155,-157,-158,-160,-161,167,-16 8 , - 1 7 0, 176-177-186; **Scolecite** from Poonah, (13193), from Iceland (13194-95), with splendid terminations in stout prisms, inclined pyramids, from France; *mesolite,* (see 13201), *thomsonite* (note 13213, 13215,-216,-217), *comptonite,* 13223; *hydronephelite, chlorastrolite, zonochlorite, episphaerite, sasbachite, aqua-acetosa*(?) (13244 beautiful little balls bristling with points), *gonnardite, lawsonite,* all from Tiburon Peninsula, Marin Co., Cal. in blue-gray crystals in a glaucophane schist bring the reviewer to the Micas.

The Micas assume a preponderant interest in the Bement collection by reason of the magnificent phlogopites which were obtained in a large measure from the Willcox cabinet, and represent the personal efforts of Mr. Willcox who, probably with Mr. Jefferis, explored the northern New York and Canadian areas. It will be impossible to dwell upon them. The numbers that belong to notable specimens in Muscovite are, 13,307, 13,308, 13,314, 13,336, 13,337 (these two last *green* from Lincoln Co., N. C.) 13,344a, 13,346, 13,349, 13,352, crystal of mica pierced by beryl.

Following muscovite come *pinite paragonite, cataspilite* and *euphyllite,* in a position, which as far as pinite is concerned, seems anomalous. **Lepidolite,** has some fine examples in the Ural specimens (13406,-409), many Maine and Haddam Neck, Conn. crystals—with the curious fibrillar envelope—13423,-425, 13427,-429; *cookeite* follows, *zinnwaldite,* (cryophyllite); *Biotite* opens with a remarkable, apparently undescribed twin, a revolution through 30° of one crystal above a second, the two uniting, with the edges bisecting their alternating prismatic faces (a much larger form of this is in the collection of W. F. Ferrier of Toronto); this specimen is from Servia; under biotite, *rubellan, manganophyllite, voigtite, pseudobiotite,* are shown.

The **Phlogopite** is the central point of interest in the micas, and for North America nothing finer probably exists. These mammoth crystals and groups of crystals are from Hammond, N. Y., Natural Bridge, Summerville, Rossie; Perth, Canada, Ontario, Burgess, Ottawa river, and represent a careful selection; (Note 13481,-483,-489,-497,-499,-501, -502, -503, -504, -508, -510, -512, -515, 13516,-517,-518,-519,-522,-527,-528,-533,-537, 13544,-548,-549).

Succeeding come *lepidomelane, alurgite, rastolyte, roscoelite, margarite, seybertite, xanthophyllite,* (Note 13614), *chloritoid, ottrelite, clinochlore,* (Note 13605, 13610, 13612,-615,-618,-620,-622,-626,-631,-633,* Tilly Foster, -634), *prochlorite, penninite* (13644), *grochauite, corundophyllite, klementite, metachlorite, cronstedtite,* (13675,-86), a very striking series; *thuringite, chamoisite, stilpnomelane,* (13697, 13701) *strigovite, diabantite, aphrosiderite, delessite, rumpfite, epichlorite, epiphanite, hullite, ckmannite, chlorophaeite, jefferisite, protovermiculite, baltimorite, kerrite, hallite, dudleyite, willcoxite, vermiculite, pyrosclerite, roseite,* (13739) *philadelphite.* This list, recorded here, to show the extent of the collection, ends with Serpentine, which asks no long detention; the most important numbers here indicate pseudomorphism and are 13762, 13767, 13770, 13774,-775, 13808,-811, 13813, 13816, 13818,-819, 820,-21,-22,-23,-24, 13826-28 13830. *Cerolite, webskyite,* (black pitchy particles on edges of a dolerite splinter), *hydrophite, aphrodite, jenkinsite,* follow.

Genthite and *Garnierite* are represented by fourteen specimens, the *genthite* from Texas, Lancaster Co., Pa., Rottis, Saxony (Rottisite), Webster, Jackson Co., N. C., and Churchill Co., Nevada; the garnierite from Douglass Co., Oregon, and from the famous mine at Noumea New Caledonia of which No. 13,907 is the most conspicuous, (*Noumeite*), being in a broad flat cakelike mass. *De Saulesite* from Franklin Furnace, N. J. is seen in Nos. 13913-14, grass-green in color in purple fluorite. *Pimelite,* Alipite, precede the talc specimens which contain familiar pseudomorphs, [*amphibole, chondrodite, humite*(?) dolomite, quartz, (13919-921), spinel, scapolite, (13931)] pyroxene, epidote, magnetite (?).

Connarite in vivid grass-green lumps between fragile white crusts from Rottis, Saxony; *spadaite, saponite, celadonite,* (13956 perhaps replacement of heulandite), *glauconite, pholidolite, kaolinite, halloysite, cimolite,* (altered augite), *montmorillonite, razonmovsky,* leads to *Pyrophyllite.* There are a number of interesting specimens in this group but some handsome examples from the Chesterfield Dist., S. C., from California, (Willcox), Lincoln Co., Ga., Orange Co., N. C., (Willcox), claim preeminence. *Allophane is pre-*

sented in encrusting forms, green to blue, of much prettiness; then follows the *collyrite, schrotterite, miloschite,* so-called *teratolite, selwynite, chrome-ochre, wolchonskoite,* with individual specimens, or several, under each species.

Cenosite from Nordmarken, Sweden, is seen in yellow-brown small crystals, with diopside, apatite, ripidolite, and magnetite (14063, 14064); *thaumasite* from Sweden and New Jersey, *uranophane* in crusts and yellow tufts of needle crystals; *chrysocolla,* No. 14096, from Rockland, Mich., and fine uralian examples, and the opallike glassy pustulose surfaces from Arizona; *chloropal, anthosiderite, hisingerite, gillingite, jollyte, bementite* (14120-26), *caryopilite, neotocite, antillite, aquacreptite, barettite, bravaisite, chonicrite, leidyite, lillite,* nefeddieffite, (?), *persbergite, picrosmine, pihlite, pilinite* (minute needles in a feltlike mass), *polyhydrite,* (finely haired spherical lumps, united in an irregular mass), *quincite, restormelite, talcosite, xylotile* complete this section of the hydrous silicates, and the titano-silicates are next encountered, a little more stirring and phenomenal in crystallographic interest. Species 289. Specimens 3719.

TITANITE; the Titanates.

The Zillerthal specimens (Nos. 14164-69) are typical, and su·perior; No. 14164 is a superb twin of some historic interest, as having been described and figured in Von Rath's obituary of Hassenberg, and published in the Neues Jarbuch für Mineralogie in 1874. Following these Tavetsch and Sulzbach, Binnenthal and Blindenthal, Pfitsch, Oberwald and St. Gothard, Sedrun, Rueras, Zermatt, Sella, are well represented, with many beautiful examples of the associated adularia albite and byssolite. The twinning of course is preeminent, and admirable types of the sphene habit are shown. 14204 is a handsome specimen; 14206, interesting; 14209 unusually good; 14212 a wheel-shaped intersection, green with brown edges on calcite; 14220 coffee-tinted tips twinned on *a,* and upon a chlorite saturated quartz. A flattened crystal from Tauery, Austria, translucent-brown, is seen in 14231, a really beautifully modified crystal. Naturally the titanites from Renfrew Co. Canada, have been carefully selected, almost invariably with reference to crystallographic interest; 14247,-243,-248,-250,-251,-252,-273, are admirable, and 14252 is well developed. Again the standard rises in the Bement specimens, in those from Tilly Foster, Brewsters, N. Y., as in 14278, 14281. 14305 is a *lederite* from Natural Bridge, Lewis Co., N. Y., associated with loxoclase. The huge wall-case specimens from Renfrew Co. are remarkable, one of them a splendid twin.
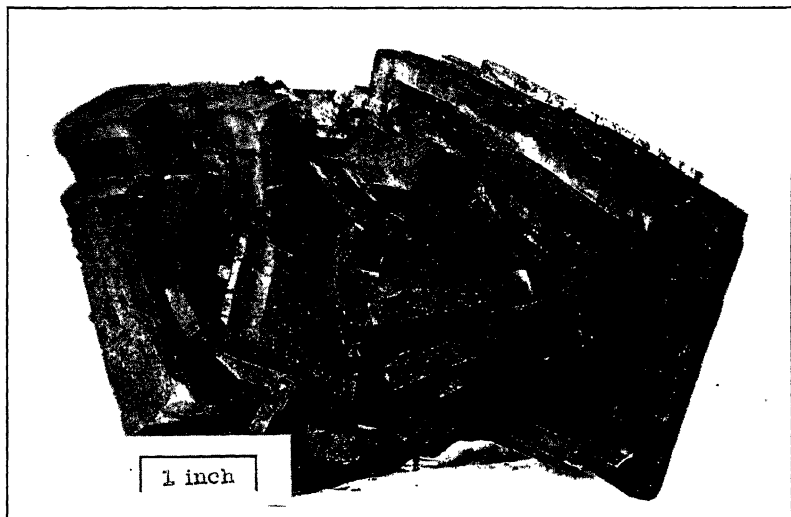
BARITE
Frizington, England
Bement Collection, American Museum of Natural History
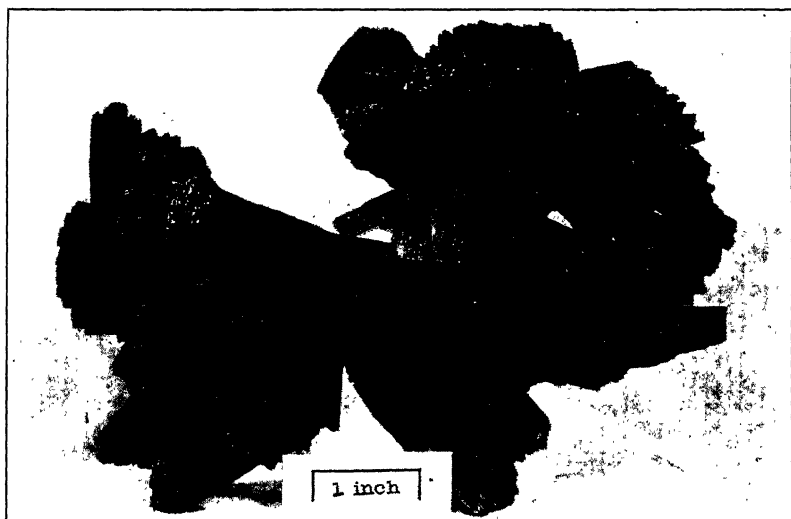
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Frizington, England
Bement Collection, American Museum of Natural History

Keilhauite, Guarinite, (now supposed to be *Hiortdahlite*), *Tscheffkinite* follow; *Astrophyllite* (typical from Colorado, Norway); *Johnstrupite, Mosandrite,* (14331 broad flat prisms, dullbrown upon black mica), *Rinkite,* (14235, 14333, 14334 from Greenland,) precede **Perovskite.**

The perovskite specimens are excellent, and they come from the Urals, Switzerland, and Magnet Cove. Note 14335-14345; 14348-14351, (magnetite extensively developed in many); 14353,-55,-59; *dysanalyte* follows. Species 10. Specimens 152.

The **Niobates** and **Tantalates** open with **Pyrochlore** (14367), *koppite, hatchettolite* (14368-370 from Mitchell Co. N. C. collected by Hidden and Ralston). **Microlite** is presented in splendid form, the specimens from Amelia Court-house having extreme value, 14375, 14376, 14380 challenge admiration, but 14382 representing 2 xtals (of which by-the-by *10* are called for) and showing planes of *a, o, d, m,* dark garnet and honey-yellow in color, is magnificent; 14384 is a remarkable example, translucent and hyacinthine in color; again 14386, 14387, 14389, 14390, 14392, 14393-94 are all admirable. *Pyrrhite*(?), *Fergusonite, Kochelite, Sipylite* lead to **Columbite.** Naturally the selections are here of a high order as American localities furnish adequate or notable specimens. Crystallographic interest predominates, as to the collector columbite possesses no other charm. Note 14426,-427,-428,-430, all from Stoneham Me.; these are succeeded by a long series from Europe and America, of which, distinguished by beauty and certainly by price Nos. 14431, 14433,-437,-442,-446-450-456-457-469 may be mentioned.

Tantalite, Stibiotantalite (a specimen in the collection from L. Cahn and received through the Bruce Fund, No. 14421, is a marvellous synthetic aggregate from California), *Skogbölite, Mengite, Tapiolite, Yttrotantalite, Samarskite,* (Mitchell Co., N. C. prominent): 14496 was from Dr. C. Hintze, apparently obtained by Mr. Bement in 1875; *Ännerödite, Hielmite,* (14513 a small black mass, dull, embedded in a fragment of a large *beryl* crystal), *Aeschynite* (14504,-05,-06,-07 a black crystal dislocated, with zircon on feldspar, 14511), *Polymignite, Euxenite,* (14516 well developed from Norway, also 14517-18), *Polycrase* (14524, a series of 18 fine crystals from near Marietta, Greenville Co. S. C, 14525 from Norway), complete this section, which perhaps offers on its chemical and physical side the greatest interest. *Rogersite* from Mitchell Co. N. C. on samarskite is from the Ralston collection. Species 23. Specimens 153.

The large group of phosphates, arsenates, vanadates, antimonates, was one in which, at many points, Mr. Bement ex-

erted all his skill to excel; his **Apatite** embraces 204 specimens and his **Herderites** have been the despair of collectors.   The group has many rarities and while declining in sections to amorphous conditions is very usually a field of brilliant crystallization. With such phases, Mr. Bement always took a heightened interest (as all do) and plentifully filled his cabinet with beautiful illustrations of them.

Xenotime, so unexpectedly associated with New York Island rocks, begins with 14526, a large red-brown crystal, well developed, on a xenotime mass.   It is from Tvedestrand, Norway, 14537 from Colorado is exceptional, 14539, also from Norway is much modified, "wiserine," appears in 14545 from St. Gothard, Switz., in two tiny transparent yellow crystals associated on the matrix with rose hematite and white feldspar; **Monazite** makes a good showing; 14563 is well developed with black mica, 14564 is large, 14566 brilliant little yellow transparent crystals with hematite, rutile, albite and quartz, 14568, 14569,-70, 14573, 14574 (tabular), 14577, 14579 (two sharp brown crystals in feldspar between two layers of black mica), 14580, 14581, 14582 (complete), 14583 (on the original label there is an insistent statement from B. Stürtz that Mr. Bement receives and absorbs the *best*), 14585 is from Alexander Co. N. C., a twin, "fine gemmy and perfect," 14588, 14590 (very handsome) are all worthy of close attention. The North Carolina specimens seem to be all Hidden finds, and are *pre-eminent*.   14597 from Arendal Norway is a Stürtz specimen showing clean-cut and symmetrical development of faces. 14615 is the so-called "turnerite," (the original turnerite came from Dauphiné; its identity with monazite was established by J. D. Dana in 1866), in bright little yellow crystals on quartz with octahedrite.   Shepard's *"Edwardsite"* is shown in 14616 from Chester, Mass.   *Berzeliite,* many crystallized (14559-625), *Monimolite,* (in minute crystals), *Carminite,* (in crystals 14628), *Pucherite,* (well shown, 14630, 14631,-632,-635 in beautiful crystals sprinkled over surface from Schneeberg, Sax.), *Caryinite* follow.

The tryphylite group is handsomely displayed, beginning with tryphylite itself, whose numbers 14650,-51,-55, 15184, are noticeable; *lithiophilite, natrophilite,* lead to **Beryllonite,** of which there are two entries 14658-60, comprising seven crystals, and showing the frosty surface, so characteristic, which may be due to inclusions. Then the very beautiful series of **Herderite** succeeds in which 14663, 14669,-70,-71,-72,-74,-75 easily take precedence and are indeed choice examples of the species.   Upon 14663 Mr. Hidden has written the note: "the largest crystal known, has all the planes

now credited to the species i. e. 13 in all," 1884; Hidden, Towne, Cahn, Perry, Schernikow, Kunz, were the sources of these remarkable specimens. Among the very fine *hamlinites,* (five entries) is No. 14684, with which was a note to Mr. Lazard Cahn, from Prof. Penfield in which that great mineral explorer writes: "I have finished my analysis of hamlinite and find that it has really a very remarkable composition expressed by the formula [Al(OH)$_2$]$_3$ [SrOH]P$_2$O$_7$, with some OH replaced by F, and Sr by Ba." That was Nov. 1895, following the statement in Dana's Sixth Edition that the "exact composition was undetermined."

The **Apatites,** making up 204 specimens, are very handsome; among European specimens attention may be called to Nos. 14735,-42, 14744 (glassy with epidote and byssolite), 14745,-52,-64; 14765,-66,-67, (these three last are superb specimens, 14765, tabular, much modified, of a soft evanescent purple hue; 14767 complex intergrowths), 14757,-58 tabular, 14770 modified summit, 14776 a group of tabular forms, 14786 (curious overgrowth and remade crystal), 14794, flat, tabular; 14804-06 from Ehrenfriedsdorf, Saxony, beautiful purple tables, 14831-41 (very pretty English suite); handsome Ontario crystals, (note 14847,-845,-853,-851,-857,-879,-880,-889,-96). The Haddam Neck series is a good one, and the Tilly Foster specimens strong. *Francolite, Staffelite, Phosphorite, Pseudoapatite* conclude the entries. A much larger number, not mentioned, are of extreme beauty and interest.

There is one specimen of *Svabite.* **Pyromorphite;** note 14954,-57,-62,-66,-68,-970,-71,-72,-73,-74,-76,-86,-88,-90,-92, -94, -97,-15000, 15020: **Mimetite,** 15037,-052,-053,-054,-059: **Vanadinite,** are displayed in a superb group of flashing, bright, crystallized specimens, with *endlichite* in many examples, (note 15158), and two hedyphanes. There are some unusually fine specimens among these of surprising distinctness and rich color. *Wagnerite* in exceptional development appears in the collection—the numbers—15173,-74,-75,-76,-77,-78,-79 are remarkably good, and a wall-case specimen has an extreme interest from its great size. *Spodiosite, triplite, triploidite, Sarkinite,* (15,200,-202 are striking), *Durangite* (3 very fine orange crystals), *Amblygonite, monetite,* **Olivenite,** (note 15216,-223,-226, 15230,-233), Libethinite, (15243,-245,-246), *Adamite* (some handsome examples, 15251,-252,-254,-256,-260), ·**Descloizite,** a good series from New Mexico, (See 15274,-279,-280,-282,-289,-293), follow.

Then comes *Eusynchite, dechenite,* (15301 from Arizona, 15303-4 from Bavaria), *brackebuschite* from Argentina (black crystals in cavities), *psittacinite, mottramite, vanadiolite, erinite,*

pseudomalachite, (15317 *phosphorocalcite,* green mass), under these are found *dihydrite, ehlite, phosphorocalcite, lunnite;* 15321 is a very fine specimen with a striking polished porcelainlike surface. **Clinoclasite,** (15342, 15334,-35,-36, 15341,-42), forms a very pretty series. *Chondrarsenite, dufrenite,* (15374,-368,-72!!) ; **Lazulite,** 15384 superior in color and quality with siderite on slate, 15383 translucent at the apex, 15381 very handsome showing twins, greatly improved by development by Alfred C. Hawkins; *tavistockite,* (15391 good) ; *arseniosiderite, allactite,* interesting crystals, 15387-408; *synadelphite,* (15410) ; *flinkite, hematolite,* crystals (15413,-16), *arseniopleite, atelestite,* (yellow crystals over matrix), **Struvite** (good crystals, 15421-15422), *guanoxalate, redondite, collophanite, hopeite,* (15419 an admirable specimen), *dickinsonite,* **Roselite,** a fine series of specimens, 15453, 15452, 15451, 15450, especially striking and choice, *brandtite, fairfieldite, messelite, chlorotile, lavendulan, reddingite,* brings the review to Vivianite.

The feature of the **Vivianite** series is the handsome specimens from Redruth Cornwall, England, (15470,-71,-78), two remarkably strong groups of crystals from Victoria, (Wannon River), Australia, (15481,-483), and 15488 from Bavaria, bright well formed crystals on pyrite. There follows symplesite, (15491), *hoernesite;* **Erythrite,** many beautiful examples of this brilliant species, (Note 15,502,-01, 15500,-498,), *Cabrerite, Annabergite, kottigite, rhabdophanite, churchite,* Scorodite, (Note 15518,-23,-24,-25) ; *strengite, barrandite;* **Variscite,** (15543,-544,-545) ; *zepharovichite, koninckite,* (15429,-39), *stercorite, haidingerite,* (15560), *brushite, pharmacolite,* (15554, acicular white radiations tinged pink by cobalt salts), *metabrushite, newberyite, wapplerite, hureaulite, hemafibrite, conichalcite,* (15568,-64, mostly light-green reniform masses), *bayldonite, leucochalcite,* Euchroite (15572,-74,-75,-77,-78,-79), *volborthite* (15593), *cornwallite,* (15580-81), *tyrolite,* (among these specimens chalcophyllite may occur extensively), *chalco-phyllite, veszelyite, ludlamite.*

Wavellite affords an opportunity for some color display, and much variation in arrangement; 15605, light-green spheres on chert; 15607, globes, dark-green, on chert; 15613 large green radiations on chert from Garland Co., Arkansas; 15614 dark-green ball with surface composed of crystal terminations, Ark.; 15616 from Cork, Ireland, light-green hemispheres on black slate; 15619 yellow hemispheres scattered over sandstone matrix, from Bohemia; 15623, a Kapnik specimen of small yellow spheres on the tips of tiny white quartz crystals, the stalactitic phases (15626,-628,-630,-631, 632, some with crystals), globular masses from the Hot Springs,

Ark.; an interesting association (15643) from Kapnik, Hungary, showing transparent yellow spheres, with quartz, tetrahedrite, chalcopyrite, galena.

The section continues with *Fischerite, Peganite,* (Note 15669), **Turquoise** (Note 15655,-57,-58,-62 large oblate mass in trachyte), *Wardite* (15670), *sphaerite,* **Liskeardite, Evansite,** (15680, hyaline soft encrustation on a cellular porous rock), *coeruleolactite, attacolite, berlinite,* **Pharmacosiderite,** (15683 grass-green cubes in strong crowded groups), **Cacoxenite** (15689 exquisite papillose spheres, bright yellow, structure resembles the disk of a sunflower—made up of minute rods); *Beraunite (eleonorite), picite, delvauxite,* **Childrenite** (15706,-07, 15708 a remarkably large crystal honeybrown, the usual top outline, with chalcopyrite on chloritic slate, (15722 is a Bruce Fund specimen, a superb specimen with thickly clustered characteristic crystals), **Eosphorite** (15713), *mazapilite,* (15715 a handsome example), *calcioferrite, borickite, richellite.*

Liroconite is presented in five excellent specimens (15723-27); of these 15724 and -25 are very handsome; and the series succeeds in **Chenevixite,** *henwoodite, chalcosiderite* (note 15734,-5,-8), *andrewsite, Plumbogummite* (the four specimens 15741,-5 are interesting), **Torbernite,** (well shown in strong and rich examples, 15744,-46,-47,-48,-50,-52,-55,-56,-58!!) *zeunerite,* (15763,-64,-65,-66,-67), **Autunite** (15770), *uranospinite, uranocircite, trögerite, walpurgite, rhagite,* **Mixite** (15787 delicate green mottlings in chains or veins in quartz, from the Tyrol, 15789 from Tintic, light-green plumose or mossy tufts of acicular crystals), *schneebergite, bindheimite, romeite, nadorite, ecdemite,* (heliophyllite), *ochrolite, ammiolite, barcenite, dahllite,* **Diadochite** (15816 a dark-brown resinous gumlike material on barite), *pitticite, svanbergite,* (15821,-23 from Sweden, good!), *beudantite,* (15825 *dernbachite,* from Nassau, and originally Trautwein's, is characteristic), *lindackerite.* Species, 155. Specimens, 1144.

The **NITRATES** contain Soda-Niter, Niter, Nitrobarite (15831-2 octahedrons made up of $+$ and $-$ tetrahedrons). Species, 3. Specimens, 6.

The **BORATES** open with Nordenskioldine, followed by *Sussexite, Ludwigite, haidingerite, pinakiolite, szaibelyite,* **Boracite** (15842 is a group of about 30 crystals showing *a, d,* $\frac{o}{2}$, etc., 15845 is another), rhodizite, (15850 small but definite crystals), *winkworthite, warwickite,* **Howlite,** *and Larderellite.*

Colemannite attracted Mr. Bement; it was announced (1883), when Mr. Bement was most actively engaged in collecting and the splendid examples, with few exceptions purchased from Dr. Foote,

cover the Catalogue from 16072 to 16117. Nos. 16076,-077,-078,-080, 083,-084,-087,-090,-097,-100,-102,-103,-104,-105,-112,-114 (remarkable tabular form), -116, are exceptionally good, and demand examination. *Pandermite, priceite, pinnoite, kaliborite,* **Borax, Ulexite,** *bechilite, hayesine, hydroboracite* complete the section. Species, 23. Specimens, 85.

The **URANATES** contain typical specimens, though, except as they are crystallized in *bröggerite, clevcite* and *chlorothorite* they do not challenge enthusiastic notice. They comprise Catalogue numbers 16134-16209. Under **Uraninite** 16134, 16144, 16148, 16149 (Branchville Conn.), 16152, 16153 (very good *clevcite* o and *a* distorted and with parallel growth), 16154, 16157 (cubo-octahedral), 16158 (twin *cleveite*), 16159 (bröggerite), are conspicuous. **Gummite** is displayed in many specimens from Mitchell Co. N. C., and in crystallized examples; also showing the highly picturesque combination of the uraninite nucleus, the orange zone of gummite, and the sulphur-yellow pulverulent phase of uranophane. Note 16191, 16193, 16196, 16198, 16200, 16201, 16203, 16162 is *eliasite,* in uraninite. Chlorothorite, all from Hidden, is shown in 16160, and in 16204-06. Carnotite (15871; 16212-216), and Uranosphaerite brings the visitor to the remarkable species of the Sulphates and Chromates. Species 5. Specimens 47.

Among the **SULPHATES,** etc., barite, celestite, gypsum, anglesite, linarite, crocoite, brochantite, herrengrundite, leadhillite, chalcanthite, kröhnkite, langite, botryogen, pickeringite, amarantite, natrochalcite (the latter a recent ornament), form some of the distinguishing features of collections, while anhydrite, the interesting vauquelinite, hanksite, blödite, lanarkite, occur here, and the unusual spangolite, sulphohalite, connellite, picromerite, and felsobanyite as well.

In the Bement series **Mascagnite,** *taylorite,* **Thenardite** (16218-232, a good lot), *aphthitalite* (16233, a superb specimen, clustering flat, rhombohedral plates, as an efflorescent investment of lava crusts), and **Glauberite** (note 16240, 16236, 16235) open the group.

Barite has been so much enriched by the splendid finds in England that perhaps in color, solidity and effective combinations (though defective in crystallographic variety) it stands well up among the most decorative of the mineral groups. In the Bement Collection it is represented by one hundred and seventy-nine specimens. Among the Cheshire examples note 15890, also Buckingham, Va., (16040); De Kalb, N. Y. (16043-45); Bad Lands, S. Dak. (16047-48); Montgomery Co., Pa. (16058); Colorado (16061--

BLUE CELESTITE
Texas
Bement Collection, American Museum of Natural History
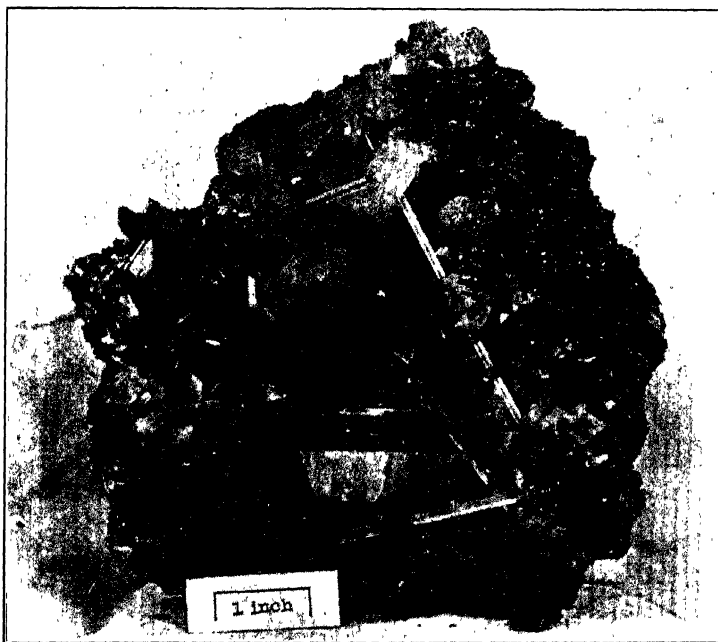
GYPSUM
Cartagena, Spain
Bement Collection, American Museum of Natural History

64); Apishapa, Col. (16166-170), (16171-178), Sterling, Col., Schemnitz Hungary (16020, 16025); Felsobanya (16026, 16021, 16010, 15977, 15974, 15976); Auvergne, France, (15998); Pribram, Boh. (15991), (16012-13 stained with realgar); Freiberg, Saxony, Kremnitz, Hungary, (16014).

Among the English specimens the following numbers are particularly fine 15923,-926,-922,-924,-921,-919,-918,-955,-958,-952,-960,-907,-905,- 15900, 15938, 15895, 15943,-937,-938, 15953 (peculiarly composite). This whole group is admirable in its firmness of outline, strength, and physical perfection.

Celestite is less varied than Barite in coloring and in disposition and development; sulphates seem to have generally less crystallographic flexibility than many other groups, though they form splendid cabinet features. In the Bement Collection there is an admirable series from Sicily, (Note 16195,-96,-97, 16201,-202,-203,-211,-212,-214,-215,-219); some striking pieces from Germany (16234,-233,-236); the English examples, (16246 crystals embedded in gypsum; note also 16256,-258,-259); the Scharffenburg, Sax. interesting low crystallized surfaces; the Erie Lk. typical large blue wonders; unusual specimens from Tennessee, (16281), from Lampasas, Texas, and the unique affairs from Cumberland, Md. and from West Va., described by Williams (16270,-271,-287,-288), with finally the associations of Colemannite and Celestite from Bernardino Co., Cal. In this group there are three specimens (stout small pale crystals) from Rossie, N. Y. (16283-5).

The Anglesite opens with a strong marshalling of selected crystals (white in the glistening gray galena ore) from Monte Poni, Sardinia (16314-349), followed by good Müssen Germany specimens; a peculiar prismatic yellow mass from Portugal (16355); the Broken Hill Mines, N. S. W. glorious crystallizations (16360-369); the blue mixtures of sulphates of lime and lead from Boleo; a few Derbyshire England crystals, a Tasmanian, (16381 white opaque tabular intersecting crystals), and the Phoenixville, Pa., veterans, among which 16383,-384,-388,-385,-390,-392, are conspicuous.

The **Anhydrite** contains a number of good crystal specimens showing the pinacoids and domes in a typical manner, (Note 16397, 16399, 16400, 16402). Then comes *hydrocyanite,* one specimen; and the next step brings the astonished visitor to the **Crocoite** specimens from Mt. Adelaide, Dundas, Tasmania, which may be justly considered as among the marvels of mineral growth and color. The Berezov specimens from the Ural Mts. have much interest, and are good; their excellence only retreats into an inde-

terminable quantity by comparison with their brilliant companions. Among the Russian specimens 16406,-407,-408 are noticeable. Then come the Tasmanian jewels—Here (16409) is a six-inch scarlet pencil, channeled, rectangular cross section, showing oscillations of the prisms; here (16410) a marvellous radiant group of red prisms, starting from an attachment at one end, and developing separate terminations (prisms, domes, and pyramids); here (16412) two divergent crystals—prismatic columns—made up of several prisms, the stouter hollow, and the shell showing small faces of pyramids, the smaller a coalescence of four crystals—all terminated; here (16414) a wonderfully effective thicket of crowding prisms, sprouting from limonite, all tubular columns; here (16415) a gloriously brilliant group of prisms, interwoven and intersecting; while additional numbers as 16418,-419,-422,-423 repeat the impressions. 16428 is a specimen from Minas Geraes, Brazil,—a web of narrow steep crystals on quartz—Dana's Fig. 4 on p. 913.

Phoenicochroite, Vauquelinite, follow. Two rare specimens of *Sulphohalite,* both obtained from Hidden, show the rhombic dodecahedral form, 16443 being especially fine. *Caracolite, kainite,* (Note 16446), *connellite,* (16449 exquisite microscopic mount!) precede **Hanksite.** There are of course some admirable hanksites (16452, 16456,-457,-458,-462,-464,-465).

Leadhillite is a species of some rarity and, except for the Granby, Mo., specimens, seems in collections solely represented by examples from its nominative locality. The characteristic platy six-sided structure of this monoclinic species is well shown in the Bement series: 16467,-468,-469,-470,-472, from Leadhills, and 16474,-475, 16477-85 from Missouri. 16473 is from Switzerland, white bacillary crystals encrusting galena; 16476 is from Sardinia, 16485 from Lake Valley, N. Mex., and 16486 (with Caledonite) from New Caledonia. There are four entries under *Susannite.* *Alumian* in a small block (16491) bluish-white, microscopically crystallized, and also just minutely granular, precedes Brochantite. Under *brochantite* the numbers of more striking beauty are 16493, 16500, 16502,-503, 16505,-506, but none quite rival the recent handsome yield of Chuquicamato, Chili. **Lanarkite,** (16508,509), *dolerophanite* (scoriaceous, porous, brown, lava specimens from Vesuvius, with crystals), **Caledonite,** (especially good in 16517, 16518, and 16519), **Linarite,** (16520-16534), *lecontite* (16544 a crystal), *mirabilite* and *szmikite* lead to gypsum.

Under **Gypsum** there are in the Bement Collection some most splendid, and many interesting or unusual specimens. The magnificent Sicilian crystals will first elicit admiration (note 16306,-

307,-308,-310,-311,-312,-313,-550,-553,-554,-555,-586, many enclosing aragonite and sulphur with beautiful twinning effects) ; following them is a series of European specimens among which the Bex Switzerland crystals are conspicuous, but numerous features of association and form, and pleasing detail are seen in less expensive and smaller pieces. Baden, Tuscany (16589) Thuringia, Hungary, Romagna, Derbyshire, Austrian Poland, Hesse, Bohemia, France Laurium (16580 long translucent crystal of a light-red color composed of a series of twinned crystals), Cartagena Spain, Bavaria, Styria, Saxony, Rome, Oxford England, (16608) Algiers, are represented.

The Bad Lands, S Dak. crystal fragments are curiously distorted but of good quality; 16599 is a gem, a number of transparent water clear crystals in parallel position from Guanajuato, Mexico; the Ohio specimens are characteristic; Lockport, N. Y. is shown in a large slab (16610) containing crystals of celestite, calcite, and dolomite, which may represent successive crystallizations; Maryland (St. Mary's river) 16612-13; delicate acicular crystals on a background of blue and green copper compounds from Cornwall, Pa. (16614) ; curved groups from the Mammoth Cave, Ky.; mosslike masses from Chili, complete the section.

Epsomite, Melanterite, Goslarite (16643 from Bingham, Utah), *tecticite, fauserite, Bieberite, Pisanite, Chalcanthite* (16658,-659,-661), *Syngenite* (Note 16665-66), *Loweite, Blödite* (16671), *Boussingaultite, Picromerite,* (good crystals in 16683,-84), *Cyanochroite, Pickeringite, Wattevillite, Krugite, Polyhalite, Picroallumogene, Tamarugite* (16687), *Tschermigite, Kalinite, Dietrichite, Apjohnite, Halotrichite, Ihleite, Alunogen,* bring the visitor to a display of color and attractive crystallized surfaces, in *Langite* (16736 is a beautiful piece), *Herrengrundite* (16743), *Serpierite* (16745 from Laurium Greece), *Cyanotrichite* (16742 from Cape Garonne France is remarkable), and to the iron sulphates in *Ferronatrite, Utahite, Amarantite, Coquimbite, Copiapite, Castanite,* and *Römerite.*

Kröhnkite is shown in the Bement series (16725,-26,-28 (phillipite)), but the splendid crystals from Chuquicamato, Chili, are only represented by a Bruce specimen, 16727.

Fibroferrite, Raimondite, apatelite, Glockerite, pissophanite, Carphosiderite, Alunite, Sideronatrite, Botryogen, urusite, Voltaite, Jarosite, (16805-812), *Zincaluminite, enysite, Ettringite, Löwigite, Johannite, Voglianite, Zippeite, chalcomenite, magnolite, Durdenite, uraconite, uranochalcite, Uranopilite, Medjidite,* close the long phalanx of sulphates, chromates, and tellurates. Species 102. Specimens 898.

The **TUNGSTATES** open with a good series of **Wolframite** succeeded by some exceptionally nice **Scheelite**. Typical wolframite from Zinnwald, Bohemia, (16867 is a twin, composition face *a*), are shown; 16869 is a heavy large group: then follows Saxony, Piedmont, Hungary, and Cornwall; 16875-6 from Cornwall are massive broad lamellar bands of mineral, associated with chalco-pyrite. S. Dakota is represented in 16877, a surface of small crystals, lenticular and knife-edged, and in 16879, associated with yellow *jarosite*. The Connecticut specimens are pseudomorphous after scheelite, 16880,-81,-82, (a magnificent large pyramid with faces of third order), -83,-84.

Hubnerite in characteristic specimens from Bohemia and Colorado, the latter of fine quality, follows. There are two *ferberites,* one 16886, with very pretty distinct crystals.

Scheelite commences with an Australian specimen from near Armidale, a square mass with crystals developed in a crevice; there is another (16916) which is massive enclosing black lamellar sheets of stibnite. Bohemia, Saxony, Germany at Guttanen, Switzerland, France, Scotland, England, Silesia, are represented with, of course, a good deal of emphasis laid on Bohemia. Of these the noteworthy members are 16899, 16901, 16902, 16903, 16905, (tabular, interesting, base and pyramid, crystals, curiously etched, and minutely pitted), 16906 (distorted, beautifully shagreened faces, translucent), 16907, 16909 (apparently two generations of crystals), (16918, 16919, (magnificent golden-red octahedron), 16928, 16929, (a very large yellow opaque octahedron, with faces impressed, striated, and curved). American examples are 16932 from California, a noble crystal apparently saturated with cuprotungstite, coloring it green, 16933 from Arizona, a beautiful honey-yellow group of octahedrons, and 16934 an almost perfect octahedron in quartz.

Powellite 16950-52 from Michigan is excellent. The **Stolzite** contains a famous specimen 16959, which is itself a marvelous exhibit, being a composition of separate yellow crystals, effectively distributed over a black crust; the crystals are distorted and unusual. This is from the Broken Hill Mines of N. S. Wales. It has a number of companions of only less supreme beauty, as 16954, a sparkling surface of small brown-yellow crystals, 16955 densely crowded orange crystals encrusting an opaline quartz, 16956, red-orange crystals, on a black limonitic crust, on a cellular quartz with pyromorphite, 16958 pyramids and base, in honey-yellow crystals, which are mounted on each other in composite groups, with fine rulings and associated with good crystals of *raspite,* 16962 remarkable lead-gray crystals, square prisms, surmounted by low octahedrons,

on an ashen-gray crust, 16963 sparkling yellow-orange crystals on limonite; 16965 is a green Bohemian specimen of some interest.

The Wulfenite section is a mineral flower-garden; perhaps Ruskin's curiously whimsical, perverted and extravagant words in his Ethics of the Dust are applicable here, though it is very evident that American contributions have made Wulfenite the flaming spectacle it now is in cabinets.

The numbers of especial beauty or interest are, 16967, 16969, 16973, 16974, 16979, 16980, 16985, 16989, 16991, 16993, 16994, 16995,-96,-98, 17004, 17005; these are Arizona or New Mexico specimens. There is an interesting suite from the Wheatley Mine, Chester Co., Pa. (Phoenixville), 17007-10; Corinthian specimens, and Bohemian; of the former note 17018, 17020, 17021, 17022, 17023, 17026, 17030, 17031, 17032, 17033; of the latter 17034, 17037, 17038. **Reinite** follows, *pateraite,* and the organic salts *Whewellite* (17051-058, the last a very handsome water clear twin), *Oxammite, Humboldtine, Mellite* (17061,-62). Species 8. Specimens 169.

Organic Salts.

Species 3.   . Specimens 12.

The series, as arranged, closes with a good display of less usual species or varieties, many obscure or rare, and which for convenience of access remain, as yet, unincorporated with the great body of the collection, and are arranged (*à la* the appendices) in alphabetical order. Many of these are admirable and of great value.

Adelite, a veinlike patch of pale yellow with calcite, Jakobsberg, Sweden.

Aerinite, (doubtful) a lump of blue, earthy, lamellar, from Aragon, Spain. Pale-blue specks and patches on an earthy rock, Spain.

Aguilarite, hollow and distorted dodecahedral crystals in calcite; Mexico. Two specimens, both superior.

Andorite, (*sundtite*), a terminal group of pyramids, brilliant.

Argentopercylite,=*boleite;* blue grains with green crusts on a red quartz; Chili.

Ankylite, whitish, red-yellow spots in *aegirite;* Greenland. Small yellowish grains on orthoclase; Greenland.

Anomalite, (*jeffersonite*), group of crystals. Sterling Hill, N. J.

Astrolite, stellate fibres in veinlets in a black matrix, inconspicuous; Saxon Voigtland, Germany.

Baddeleyite, grains, zirconlike splinters crystals; Brazil.

Bixbyite, good crystals on topaz and garnet; Utah.

Borophosphate, a rough brown mass, granular and dense, probably a var. of Apatite; Chili.

Britholite, a fairly good crystal, flesh-brown in the green lamellar mineral, presumably *arfvedsonite;* Greenland.

Celsian, yellowish-white vitreous spots in a compact crystalline brownish rock, in which the reddish parts may be *schefferite;* Sweden. A handsome face-yellow-white, showing basal cleavage in a schist; Sweden.

Caryinite, yellowish-brown particles and cleavage plates in rhodonite: Sweden.

Caswellite, pale white, soft, lamellar (*not* in color like *clintonite*) with garnet. Franklin Furnace, N. J. Typical, liver-brown; N. J.

Chlorothroxite, an efflorescence; Vesuvius.

Chalcolamprite, brown, well defined octahedrons in green blades of aegyrite; Greenland.

Clinozoisite, thulite-colored crystals with epidote; Tyrol.

Clinohedrite, white, to rosaceous, crystals, and splinters, with axinite; Franklin Furnace, N. J.

Cordillerite, Laurium Greece.

Cordylite, observed in dull yellowish or white crystals, with aegyrite and a white mineral, (celsian? ankylite?) : Greenland.

Derbylite, a pretty selection of very small crystals, some in cruciform position; Brazil.

Dietzeite, Chili, (doubtful),

Dipsolite, (doubtful), a square compact clay body, pale yellow, spotted with black specks; Sterling Hill, N. J.

Dundasite, coralline forms, in a porous cellular mass, showing very delicate silken radiate fibres, green-yellow; Tasmania.

Endeiolite, chocolate-brown minute encrusting crystals on a stout aegyrite; Greenland.

Epididymite, glassy crystal; Greenland. Glassy particles and especially fine crystals about a cavity; Greenland. Glassy crystals in a large mass with aegyrite; Greenland. Glassy crystals with elpidite aegyrite, etc. Greenland.

Ersbergite (of no value = aragonite).

Ferro-Manganese, a curious stalactitic slaggy flake with two broad octahedral(?) forms. N. S. Wales.

Ficinite, an indented blue-black polished crystal in pyrite; resembles apatite, a hydrous phospho-sulphate of iron and manganese; Bavaria.

Franckeite, fine specimens from Poopo, Brazil.

Fuggerite, thick four-sided tabular whitish crystals, and grouped smaller ones; Tyrol.

Geikielite, a splinter and a rolled pebble obtained by Dr. A. E. Foote from the describer, Dr. Dick.

Glaucochroite, good; beryl-colored crystals in massive garnet, with white nasonite.

Graftonite, a mixture; a coarse brown eroded crystal; N. Hampshire.

Grünlingite, gray lamellar on quartz; Cumberland, England.

Hardystonite, three specimens from Franklin Furnace, N. J.

Kallilite, a bismuth compound, yellowish, lamellar; Siegen Germany.

Iodchromate, ?, Chili.

Josephinite, Oregon.

Knopite, a black isometric mineral in cubo-octahedrons; Sweden. Large crystals, typical: Sweden. Two separate well-developed crystals, free from matrix; Sweden.

Lautarite, a porous solfataralike mass, discolored; Chili. A white crystallized encrustation on a friable salt-saturated rock, in which *yellow patches* are seen; = the lautarite. Chili. A curious pale liver-brown complete, concretionary mass, riven, pustulose, and clinkerlike(?) ; Chili.

Leonite, a small specimen with crystal: Leopoldshall, Germany.

Leucophoenicite, two specimens, in one, beautiful purple crystals, small, in a massive mixture of leucophoenicite, zincite, and franklinite; Franklin Furnace, N. J.

Lewisite, small separate and distorted octahedrons; Brazil.

Liceite, beautiful white monoclinic crystals; Chili.

Lorenzenite, crystals in aegyrite; Greenland.

Lossenite, brown pyramids, with base in a crust, thickly crowded together; Laurium, Greece. Irregular surface of crowded yellowish pyramids, (a fine specimen) upon a ferruginous rock; Greece.

Mohawkite, Michigan.

Mariposite, a light apple-green micaceous mineral, containing chromium, in dolomite; California.

Narsarsukite, honey-yellow plates and intercalations, in a porous cellular polygonal rock; Greenland.

Nasonite, Franklin Furnace, N. J.

Neptunite, the Greenland specimens.

Northrupite, group of octahedrons; California; Borax Lake.

Offretite, two specimens from Mt. Simiouse, France; White crystallizations in druses in an igneous rock.

Pearceite, resinous black specks in a hard quartzose rock; Montana. Tabular with basal face marked by triangular outlines, associated with enargite, very handsome; Utah.

Pirssonite, a single apparently perfect crystal; why orthorhombic; Borax Lk. California.

Plumbobismuthite, delicate asteriate white splashes over a dense black rock.

Rathite, a lead-gray prism in dolomite; Switzerland: (some of Prof. Solly's material was obtained from L. Cahn, by exchange with Bement duplicates).

Roeblingite, one specimen, a flake; Franklin Furnace, N. J.

Rosenite, good crystals (but of what?).

Rowlandite, a black gadolinitelike nucleus with a ferruginous shell; Llano Co., Texas.

Sauconite = lithomarge; Lehigh Co., Pa.

Schizolite, faintly brown crystals, showing terminations, with aegyrite and endialyte; Greenland.

Seelandite(?), Carinthia.

Stelzenerite, bright-green patches, on which a microscopic crystallization is discernible; Chili.

Sulphobarite, delicate white topaz-shaped crystals; Magdesburg, Germany.

Sulvanite, the specimen shows a flesh-colored mineral, granular, mixed with malachite; Burra-Burra, Australia.

Svabite, a granular decomposed rock with white small crystallizations in tufts; Pajsberg, Sweden.

Sychnodymite, very minute encrusting crystals, described as octahedral with multiplied twinning: three specimens from Siegen, Germany.

Taeniolite,(?), S. Greenland.

Taraspite, green dolomite; Switzerland.

Thalenite, flesh-colored strip in gadolinite; Sweden.

Umangite, dark-reddish mass with *blue* spots = *chalcomenite*.

Urbanite, brown-red, dark, translucent, crystallized, in lime-stone; Sweden.

Valaite, a resin from a coal-bed, seen in the coaly glittering lines of scales enfilading a slate breccia, with dolomite; Moravia.

Variolite,(?), France; pissolitic, green.

Vesbine,(?), Mt. Vesuvius. Is considered a yellow crust; the coating here is apple-green.

Waddoite,(?), Isle of Waddö; flesh-colored rock, invested with black mica sheets, with vitreous brown kernels.

Walleriite,(?), Sweden; limestone with a green laminar mineral throughout. Two specimens.

Waltherite, granular nodule; Bohemia.

Wellsite, a very beautiful surface of white crystals on corundum twinned as in *harmotome* etc.; North Carolina.

Wichtisite, a pepper and salt complex attached to slate; Finland.

Xenophyllite, bronze-red, massive lamellar, garnet-red reflections; Piedmont Italy.

Zeophyllite, balls, feebly reddish, or pink, radiate structure, with natrolite in an amygdule; Gross-Priessen, Germany.

Species 83. Specimens 116.

In addition to the summarized review of the table-case speci·mens above given there must be considered the *three hundred and nine* wall-case specimens, among which are very striking and some notable mineral exhibits, all part of the Bement cabinet. Among them are handsome examples of galena, stibnite, quartz, hematite, spinel, manganite, aragonite, siderite, cerussite, phlogopite, apatite, titanite, wagnerite, columbite, gypsum, celestite, wulfenite, barite, the feldspars, the amphiboles, rhodonite, willemite, wernerite, gar-net, zircon, topaz, analcite, apophyllite.

Perhaps it is pertinent, in this connection, to emphasize an old and useful conception, in the exhibition, for public inspection and study, of Minerals. While new devices in cases in museums, claim attention, from some minor feature of interest, or perhaps more usually, from a greater brilliancy of finish, or from richness of material, used in their construction, there can be but one satisfac-tory system of mineralogical display, viz, the long table case, con-veniently adjusted with reference to its height from the floor, and the distance of the specimens, at the back of the case, from the eye of the observer, with appropriate arrangements for access to the specimens, and for provisions for excluding dust.

It is the consequence of ignorance, and carelessness in thinking that any other plan of case (I mean any plan structurally contrasted; of course variations in the sizes of cases does not affect the typical idea of a table), could be suggested for minerals, assuming that the exhibition has in view educational results and the most favorable auspices for the examination of the specimens. The table-case, is most inclusive, in all ways, of advantages. Large and small specimens are equally well seen; they are seen with the least fatigue; they succeed in a natural planular order, permitting comparison, while it is the only method which allows a *coup d'ocil* of a group, and brings, resultantly, into one perspective the colors and forms, and permits systematic succession. Its indulgence for all labels and explanatory text is self-evident. It is the analogue of the text-book itself, where page follows page. This disjointed method of shelves, or terraced steps, is the merest folly; that is for the serious pur-

poses of exhibition. It even fails to bring out the beauty of speci-
mens, because they are not closely or well seen, and their colors
are not thrown into contrast or composition in a single field.

The glitter of glass, the laquer of metal, most meretriciously,
has been chosen by some for the substantial enduring and adaptive
advantages of flat installation. Their taste is perverted, and they
inject the functions of a decorator into the responsible task of a
curator. A very little analysis and study will also demonstrate
irrefragably that, on the score of beauty itself, the mineral speci-
men (except in large masses) suffers in stepped glass cases, where
everything becomes diaphanous and where *relief* retreats into vague-
ness, in the reflections and transparency of the case itself.

There is also a noticeable tendency to-day to restrict exhibits
in Minerals, to leave out small, less representative specimens, or
species. Except as the minuteness of the object positively pre-
cludes its exhibition this is all wrong. It is especially so in mineral
exhibits. A mineral exhibit in a museum should be an objectified
Text-Book. It should be the *whole* science. This is imperative.
Numbers of things otherwise unsuspected by the visitor, the student,
the collector, would remain hidden, and the usefulness of the les-
son taught by the exhibit just so far diminished or aborted. It is of
no consequence how far an exhaustive exhibit tires the average
visitor. He can readily pick out the attractive portions and leave
the rest. His ignorance, or inattention, or necessary indifference
ought not to exercise the slightest restraint upon the purpose of the
Museum, which fundamentally is *information, education.* An en-
cyclopedia constructed on such a plan would be ridiculous. Any
habit of suppression in a Museum should be censurable. Certainly
it is not essential to repeat practically identical things, as in identical
skulls, identical skeletons, etc., but in minerals a very great gener-
osity in the exhibit is necessary since the variations in specimens of
the same species are infinite; color, association, form, occur in reti-
nues of contrasted combinations every one of which has its separate
interest and separate beauty.

General Index

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Mineral Index

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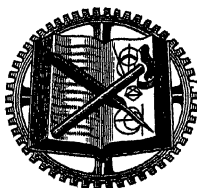
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